LONGMANS' TECHNICAL HANDICRAFT SERIES

MASONRY

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MASONRY

AN ELEMENTARY TEXT-BOOK FOR STUDENTS IN TRADE SCHOOLS AND APPRENTICES

BY

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PREFACE

THIS book has been written with the object of giving the greatest amount of information to the practical student, whilst keeping in view the requirements of the City and Guilds Examining Authorities. Examples of Stereotomy have been added, with the hope that they will prove of service to all engaged in the craft, either as draughtsmen or craftsmen.

The Author hopes at a later date to extend the scope of the work to include marble masonry and interior decoration, together with more advanced examples in stereotomy and the Statics of Construction.

It is assumed that the reader has some knowledge of practical geometry and mathematics; but the examples are described and illustrated as clearly as possible, to enable the reader who has not this knowledge to follow the method of working.

The Author, who is a practical mason, has had many years experience in Building work, and has taught the subject of Masonry at several of our London Polytechnics.

He wishes to express his thanks to Mr. H. W. Richards, Principal L.C.C. School of Building, Brixton, his earliest teacher, who imbued him with that quest after information, without which this book would not have been attempted.

To Mr. E. Burlington for his kindly criticisms and valuable suggestions, and also for his overlooking the final proofs and arrangement of the index.

The City and Guilds of London Institute for their permission to reprint the examination papers, and the publishers for their suggestions and assistance.

LIST OF BOOKS

The Author has referred to the following works during the preparation of this small text-book, and begs to acknowledge his indebtedness to the authors.

BUILDING STONE . . . . *J. Watson*

BUILDING AND ORNAMENTAL STONES . . . . *Hull*

RIVINGTON'S NOTES ON BUILDING CONSTRUCTION

BUILDING CONSTRUCTION . . . . *F. M. Simpson*

BUILDING CONSTRUCTION . . . . *Mitchell*

PORTLAND CEMENT . . . . *A. C. Davis*

GOTHIC MOULDINGS . . . . *Paley*

GOTHIC ARCHITECTURE . . . . *Bond*

CARPENTERS AND JOINERS' ASSISTANT . . . *Newland*

GOTHIC ARCHITECTURE . . . . *Pugin*

LA COUPE DES PIERRES . . . . *Lejeune*

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MASONRY

CHAPTER I

INTRODUCTION

TOOLS AND MACHINES

MASONRY may be defined as the Art of Building in blocks of stone of predetermined shape, each block being accurately cut to comply with well-known physical and mechanical laws.

The architect having prepared his design, the mason first prepares full size drawings from which templates or moulds are made to enable the **banker mason** to cut the stone to the required shape.

The mason who prepares these full size drawings and cuts the templates (usually in thin sheet zinc) is known as the **setter-out** or **mould cutter**.

Next to the architect and draughtsman, this man plays the most important part in the correct development of the stone-work of a building. He must carefully interpret the architect's conceptions, and must decide the best position in which to joint some of the important features of the design to insure stability, and to as far as possible avoid unequal weathering of the stone.

Many architects decide where all the most important beds and joints are to be placed ; but there are still many architects who leave this most important detail to the skill and experience of the mason.

The mould cutter may save his employer considerable expense in the correct draughting and cutting of moulds, and every mould cutter should have a thorough knowledge of practical geometry.

The moulds are handed by the foreman, with the more or

less prepared stone, to the **banker mason,** who, after working plane surfaces, applies the moulds to the stone, scribing the contour on the block, and working with steel tools, cuts the stone to the required shape.

The mason who places the stone in position in the building is known as the **fixer.** He should be supplied with a drawing showing each stone numbered, to enable him to place them in their correct position.

Masons who prepare and fix rough walls are known as **wallers** or **nobblers,** whilst those working and laying paving are known as **paviors.**

TOOLS

The tools in use are of many and various kinds, and this chapter does not pretend to describe every tool in use by masons. The most important tools are described; but it must be remembered that tools suited to one kind of stone, are utterly unsuitable to stone coming from another district. There are, however, many tools common to all masons, and they are described and illustrated in the following :—

Straight-edge.—A strip of wood about 3 to 4 inches wide of varying thickness, long enough to reach each extremity of the surface to be worked, with true planed edges, parallel for preference.

Hammer (Fig. 1).—The head is of cast steel weighing from 4 to 6 lbs. according to the discrimination of the mason. The shape varies considerably ; but the long-headed hammer is considered the most useful. Steel-faced iron is sometimes used but is not very satisfactory. The handle is of ash about 8" long.

Pitching Tool (Fig. 2).—Made from octagon or oval cast steel 8 to 9 inches long, having a bevelled non-cutting edge about a ¼-inch thick and set at about 80° to the back of the tool. It is used with the steel hammer in spalling or pitching off superfluous stone.

Punch (Fig. 3).—A tool used in conjunction with the hammer, in roughing or broaching the stone to shape. It is not pointed as a centre punch, but has an edge ¼-inch wide and sharpened like a chisel.

Chisel (Hammer Head) (Fig. 4).—Made of octagon or oval steel with a cutting edge from ½ to 1½ inches wide, used with the hammer in chiseling surfaces and edges of hard stones. It is a common tool for edging and jointing hard York paving.

Wedge and Feathers (Fig. 5).—The wedge or plug is of soft steel, and the feathers are thin pieces of iron or mild steel concave in shape. They are used for coping or splitting granite. In coping stone of a softer nature short punches are occasionally used (see description in chapter on conversion of stone).

Jumper (Fig. 7).—Of varying lengths, made of octagon or round cast steel, and having a chisel edge slightly rounded, and wider at the cutting edge than the diameter of the tool. It is used to drill or jump holes in hard stones and granite, and is operated by being turned round with one hand and struck by the steel hammer.

Lewising Tool (Fig. 8).—Usually made of oval steel; its cutting edge is wider than the tool, to allow clearance when cutting mortices in the beds of stone to receive the lewises.

Mallet (Fig. 9).—Of beech, hickory, or other hard wood, circular in shape, and of varying sizes, used for striking mallet-headed tools when working freestone.

Point (Fig. 10).—Similar to the punch but used in conjunction with the mallet in roughing off superfluous stone.

Chisel (Fig. 11).—Of octagonal steel of various widths, from $\frac{1}{4}$ to $1\frac{1}{2}$ inches, used for working drafts, mouldings, etc.

Claw Tool (Fig. 12).—Is a chisel having a serrated cutting edge, the teeth being about $\frac{1}{4}$-inch wide. Claw tools are of various widths, and are used after the operation of punching or pointing, to prepare the stone for the boaster.

Boaster (Fig. 13).—A chisel with a mallet head over $1\frac{1}{2}$ inches wide, used for dressing surface of stone.

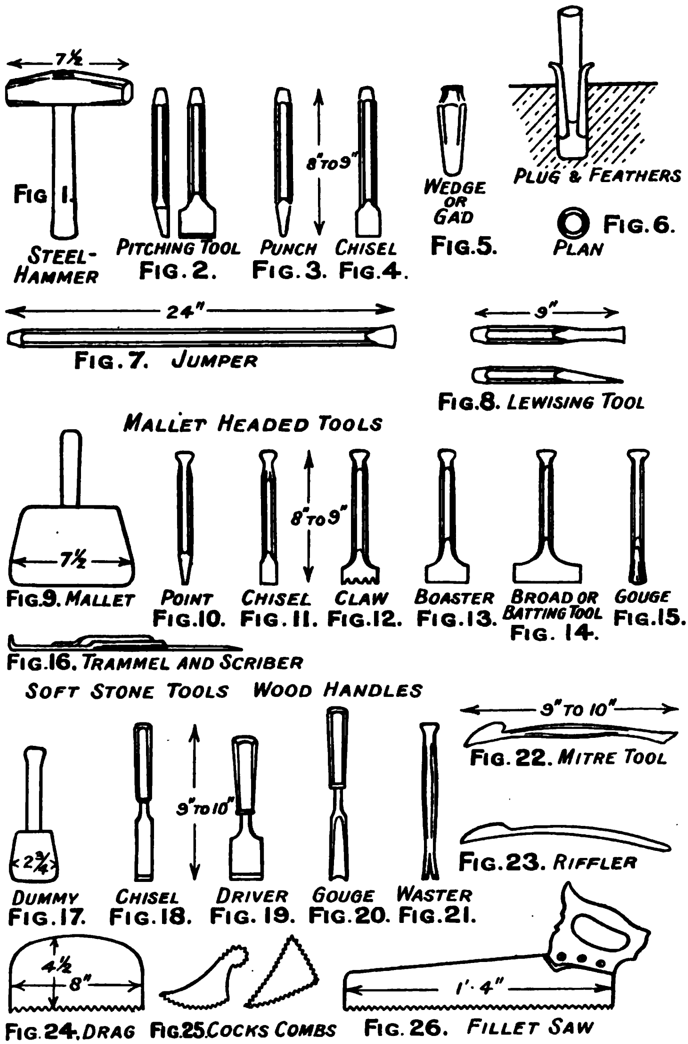
Batting or **Broad Tool** (Fig. 14).—About 4 inches wide, used for batting or tooling surfaces.

Gouge (Fig. 15).—A mallet-headed tool with a concave cutting edge, used for working concave mouldings, etc.

Trammel and Scriber (Fig. 16).—A steel tool used for scribing or cutting lines on stone, the bent end is used as a gauge scriber, for cutting a line on the stone parallel to a surface already made.

Note.—The before described steel tools are sharpened by a tool smith, who heats the tools to redness, beats them thin on the anvil, and tempers them to various hardnesses in accordance with the material to be worked. They are rubbed to a fine edge on a piece of sandstone from time to time, and when too thick for economical rubbing, are again sharpened by the smith. The mallet-headed tools should be used only in

conjunction with the mallet, and to use the mallet on hammer-



headed tools would cut and indent the wood and spoil the mallet.

Dummy (Fig. 17).—A tool made of zinc or pewter, three to 4 lbs. in weight and used for striking wood-handled chisels in working soft limestones.

Chisel (Fig. 18).—Something like a carpenter's firmer chisel, but of shorter and stiffer make, used for soft limestones.

Driver (Fig. 19).—A wide chisel, short and stubby, for dressing soft limestone.

Gouge (Fig. 20) for working mouldings.

Waster (Fig. 21).—A cast-steel mallet-headed tool, used for "wasting" off superfluous soft limestone. Its cutting edge is sometimes split as shown in figure.

Mitre Tool (Fig. 22).—Is made of cast steel, and having double-ended cutting edges of a variety of shapes; is used to scrape corners, mitres and other awkward positions where sharp outlines are required.

Riffler (Fig. 23).—A steel tool having a shaped rasp at each end, in a variety of shapes, used for filing up awkward positions in soft limestones.

Drag (Fig. 24).—Is a steel plate of $\frac{1}{10}''$ to $\frac{1}{12}''$ in thickness, having teeth of varying sizes in those grades known as **coarse, second, fine.** The drags are also made with convex cutting edges, for concave, cylindrical, and spherical work, and are then known as **circular drags.**

Cockscombs (Fig. 25) are thin steel plates of varying shapes and sizes, having toothed cutting edges for working and cleaning up mouldings, internal mitres, etc., in soft limestone.

Fillet Saw (Fig. 26).—A steel saw, having its handle set well above the cutting edge, to enable the mason to cut a kerf into the stone without the fear of damaging the corners with the handle.

Cross-cut Saw (Fig. 27).—A double-handled saw of various sizes, having coarse teeth with a good set for cutting soft limestones. A single-handed cross-cut is in use in some districts, and also at the Bath stone quarries.

Hand Saw (Fig. 28).—Steel blade about 30 inches, used for sawing soft limestone. The teeth of the saw are not shaped like the teeth of a wood saw *WWW*, but are cut at about 60° to the bottom edge of the teeth thus WWW 60°.

Iron Hammer (Fig. 29).—The head is of soft iron, and the tool is used by marble masons, letter cutters, etc. It is usually used in conjunction with a cup-headed tool (see Fig. 33).

Figs. 30, 31, 32 describe small tools mostly used by marble

masons and are usually cup-headed, that is, the head of the tool is indented like a crater, leaving a sharp edge on the outside (see Fig. 33). The iron hammer used for striking this tool thus grips it at each blow, and a sweeter or keener cut is the result. It is obvious that this quickly wears a hole in the hammer, which is filled from time to time with new metal.

Sinking Square (Fig. 34).—Consists of a brass or gun-metal stock A, and having a thin steel movable blade B, that can be set at any desired depth by means of the screw C. The blade is at right angles to the stock, and is used to test the sinking or depth of panels, mouldings, etc.

Shift-Stock or Bevel (Fig. 35).—Consists of two pieces of steel plate with distance pieces between for the stock; whilst the blade is a slotted steel plate, fitting between the two plates of the stock, and held in position by means of a brass thumb screw and washer. The blade may be set at any desired position and angle to the stock, and the tool is used for testing sinkings, chamfers, drafts, etc. These tools are sometimes made in sheet brass.

Square (Fig. 36).—A mason's square consists of thin steel plate of varying sizes and thickness. The stock is usually made in three thicknesses of metal, and is about two-thirds the length of the blade. The accuracy of the square should be tested from time to time, as it is subject to hard usage in the mason's shop. The blade should be at right angles (90°) to the stock, and the least variation means the production of bad work.

Spall Hammer (Fig. 37).—The head is of steel or steel-faced iron, and the face is rectangular, about 3 to 4 inches long by 1¼ to 1½ wide, and has a good square edge. The tool weighs from 12 to 14 lbs., and is used for knocking or spalling off superfluous stone.

Pick (Fig. 38).—Weighs about 14 to 16 lbs., and is used to roughly dress off surfaces of stone, and for reducing blocks to a required shape. It is used principally for granite and as a quarryman's tool.

Axe (Fig. 39).—Weighs about 12 to 14 lbs., has sharp edges, and is used for dressing granite to shape. A similar tool is also in use in the south and west of England at the quarries, for roughly squaring blocks of stone.

A toothed axe is also used, having the same relationship to the axe, as the claw tool has to the boaster.

Patent Axe (Fig. 40).—Has an iron-framed head which is

made to receive thin steel plates which have sharpened edges. They are bolted into the head, and when used on granite

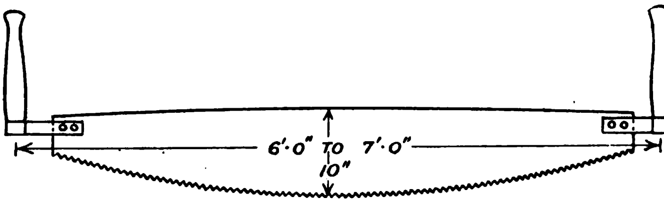
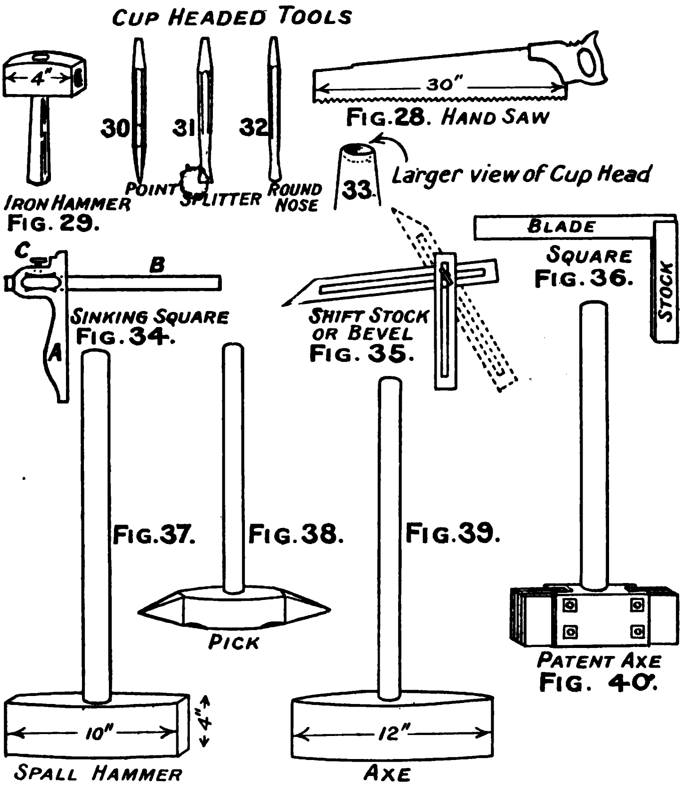
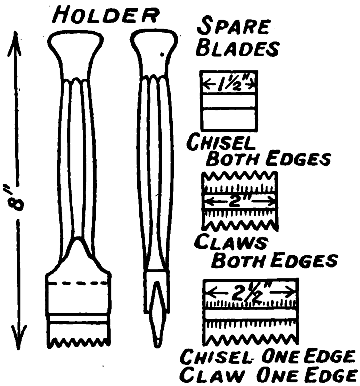


FIG. 27. CROSS CUT SAW

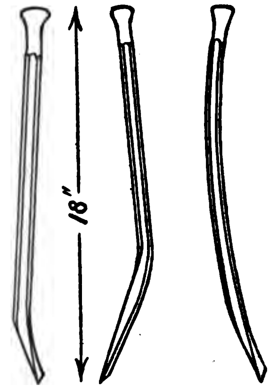


produce a good and fine surface. The plates vary in thickness, and are used in accordance to the quality of fineness required.



FAULDS TOOLS

FIG. 41.



BENT TOOLS

FIG. 42.

FIG. 44.

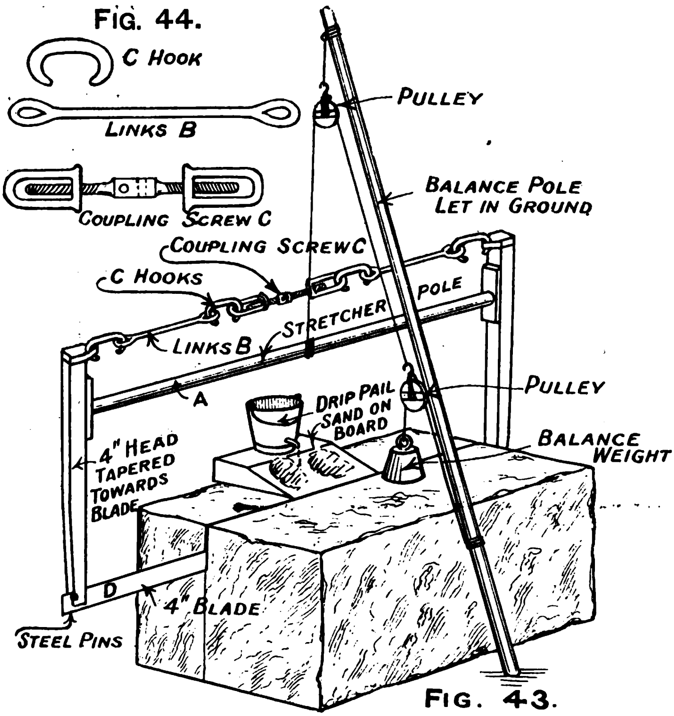


FIG. 43.

Faulds Tools (Fig. 41).—Consist of an iron handle with mallet head, the foot of the tool having a slotted pocket to receive thin steel blades of double-cutting edge. When one edge is dulled the blade is reversed and the other edge is used. The blades are made as claw tools, or boasters and chisels. They are successfully used on free grit stone and lime stones.

Bent Tools (Fig. 42).—Various types of bent tools are used for working in awkward positions. They are specially suitable when working tracery.

Frame Saw (Fig. 43). A saw consisting of timber framing with a stretching pole A, and links B with a coupling screw C. The blade D is of mild steel plate, usually about four inches wide $\frac{1}{10}$ inch thick, and is held in frame by two steel pins, the coupling screw being turned to make all taut.

The saw is balanced by means of pulleys and cord (see diagram), and is pulled to and fro whilst flint sand and water are fed into a prepared groove, friction causing the blade of the saw to pass down the pre-determined cut. The saws are made up to varying sizes, by adding or reducing links B, and using longer or shorter stretchers and blades.

The introduction and rapid improvement of stone-working machinery during the past decade, has practically revolutionized the industry. A short description of a few of the principal machines in use, may prove of interest to the reader, as it is only in the large and well-equipped shop that the latest machinery is in use.

Fig. 45 is an illustration of a **frame saw.**

The frame A is suspended from the shafts B by short connecting rods C, allowing a reciprocal or swinging movement. One or two connecting rods D couple the frame to the cranked shafting, which is driven by belt from the main shafting, or by direct connection with an electric motor. The shafts B are controlled by a screw and bevel wheel gear E, and move automatically downward, the speed being regulated to suit hard or soft stone.

The frame is arranged to take mild steel blades about six inches wide by $\frac{3}{16}$ inch thick, which are fixed by means of clips and wedges W, and distance pieces or gauges, in suitable positions.

Sand, carborundum, crushed steel shot or other grit is fed on to the stone, with a good supply of water from the sprinklers F above.

The frame saw is mostly used for cutting large blocks or

for slabbing. The frame being capable of taking a large number of blades at one operation.

Fig. 46 illustrates the **diamond circular saw,** which consists of a circular steel plate from 5 feet to 8 feet 6 inches diameter, and about ⅜-inch thick.

This plate has dovetailed notches equally distant, into

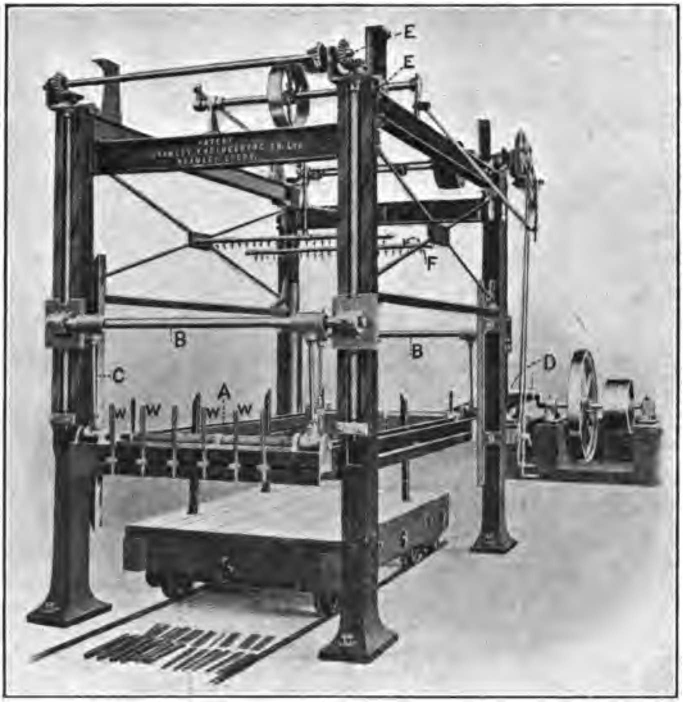


Fig. 45.

which sockets, which contain the diamonds, are keyed and fixed. The diamonds (black diamonds) are fixed in the sockets in different positions, some being in front to do the forward cutting, and others at the edge and side to cut the clearance for the plate. The diamonds placed on the side of the sockets thus act in the same manner as the **set** on a toothed saw.

Fig. 47 is a rough sketch showing the position of the diamonds.

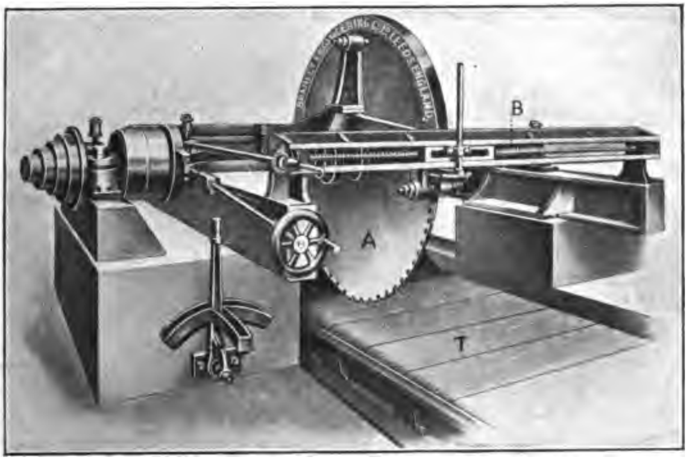

B
A
T

FIG. 46.

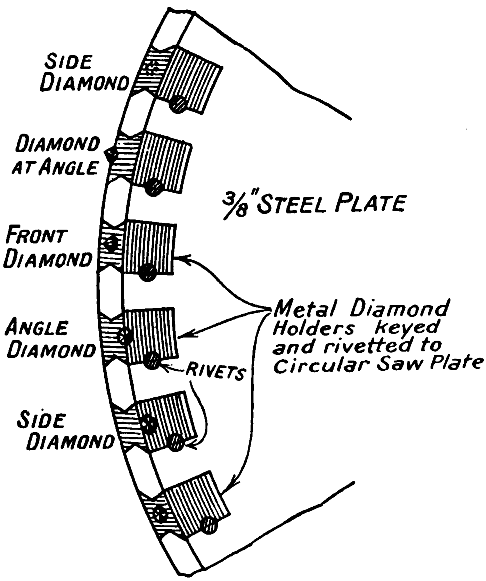

SIDE DIAMOND
DIAMOND AT ANGLE
3/8" STEEL PLATE
FRONT DIAMOND
Metal Diamond Holders keyed and rivetted to Circular Saw Plate
ANGLE DIAMOND
RIVETS
SIDE DIAMOND

FIG. 47.

The circular plate is fixed to a spindle B, and in some types of machines, the plate may be fixed in any desired position on the spindle, and the spindle has a rising and falling motion, so that various size checks may be cut from the stone. The spindle is driven by belt from the main shaft or by direct drive from an electric motor.

The block of stone is placed on the table T, and the saw plate arranged opposite the proposed cut. Whilst the saw plate revolves the table moves automatically underneath, carrying the stone, which is not fixed to the table. Carborundum is used in place of diamonds and sockets just described, and smaller saws made entirely of carborundum are used for cutting and moulding marble.

The speed of the table may be adjusted to suit the hardness of the stone.

Fig. 48 illustrates the **rubbing bed.** The circular table A

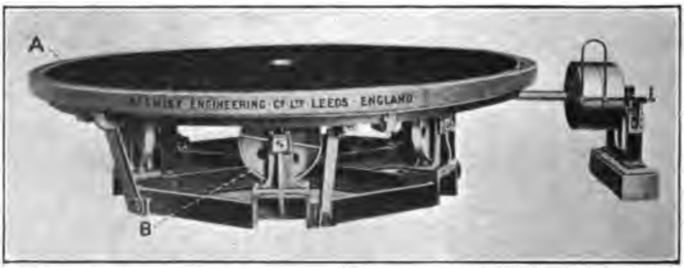


FIG. 48.

is of cast iron of from six to twelve feet diameter. It is driven by a vertical centre spindle and supported by anti-friction rollers B, making about 30 revolutions per minute, in the large-size tables, to 40 per minute in those of smaller dimensions.

A fixed trough all round the table carries away the grit and slurry. Wood beams are fixed above at a suitable distance, to prevent stones following the motion of the table. Heavy stones are suspended from a crane above, and the operator moves the stone to and fro to prevent scoring or unequal wear of both stone and table. Sand and water are fed between during the operation, and a good operator can rub plane surfaces and square other surfaces from them, with great accuracy and speed.

Fig. 49 illustrates the **moulding** or **planing machine** often known as the **iron mason** It was first patented by Messrs. S. Coulter and H. Harpin in 1872, and has been subject to many patented improvements since that date. It consists of a moving table A working in roller grooves B, with a strong and suitable vice for clamping the stone in position on the table.

The cross-head E, which carries the tool boxes in which the

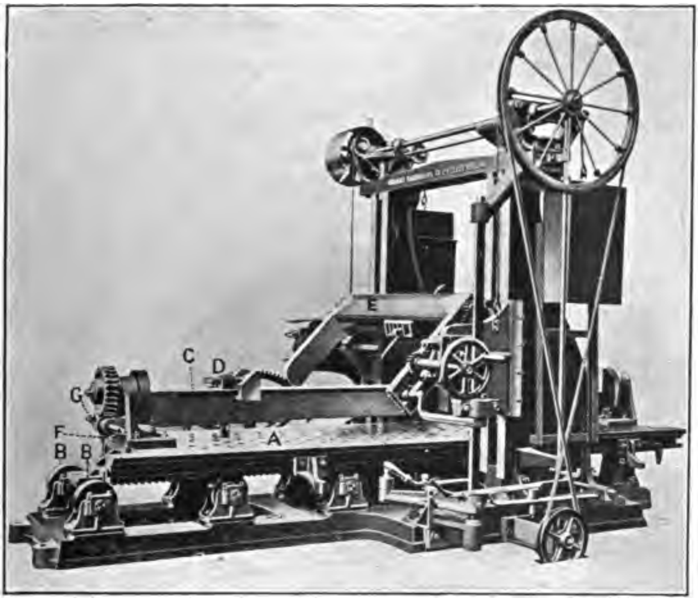


FIG. 49.

cutting tools are fixed, is so arranged that it turns over on working to the end of a stone, ready for another cut on the return of the table.

The cross-head can be raised or lowered at the will of the operator, who can arrange the cut to suit the hardness of the stone. The tools fixed in the boxes are of cast tool steel bar, and are sharpened similar to an ordinary hard stone chisel. They may be arranged to cut plane surfaces or shaped to cut elaborate mouldings.

There are many types of these planing machines on the market, all varying slightly from one another.

A rocking table C, which is shown in the illustration, enables the operator to present other surfaces to the cutting tools without readjusting the stone. The device is specially suitable for kerbs, strings, and other narrow scantlings. The stone is clamped by the vice D, the handle F working a screw and worm wheel G, enables the operator to turn the stone, and to present either top or sides to the tools with one setting of the stone.

The machines have proved invaluable in working grit stones, and the return cut helps to keep the tools sharp for a considerable time. They are successfully used for grooving the surfaces of flag or pavement stones, to give a good foot grip.

There are many other machine tools in use, in the most up-to-date stone and marble masons' shops, such as—

Carborundum saws for marble.

Carborundum moulding machines.

Pneumatic and electric hammers.

Various forms of sanding and polishing machines.

Sand blast machines for letter and fret cutting, for hard marbles and granites.

Lathes, etc.

But as these are mostly used on harder materials the descriptions are left for some future issue.

CHAPTER II

CONVERSION OF STONE

STONE when received from the quarry is in blocks roughly picked or axed to shape. Before going to the banker mason, it is cut to size, and where machinery is in use many labours are completed.

A short description of the processes involved in converting rough-hewn blocks to finished shapes in an up-to-date mason's shop, would probably be of interest to the young mason.

The blocks are selected for the special work for which they are intended and are placed under the **frame** or **rip saw** and sawn to predetermined sizes, allowing a minimum of waste.

Ashlar blocks are placed on the **rubbing bed** and faced, or if they require further sawing, placed under the **circular diamond saw**. Blocks of small size are put directly under the diamond saw and reduced to size.

A good machine with an expert operator will cut the stone in such a manner that it requires little or no labour in rubbing.

The jointing of ashlar is usually performed by the mason with hand tools.

In working cornices and strings, the large checks are cut out by the diamond saw, and the stone is then placed under the **steam mason** or **moulding machine**.

The tools are so arranged as to plane the stone to the correct mould, and when successfully operated very little fracture occurs at the end of the stone.

Joints, returns, breaks are usually executed by hand labour; but several makers of machine tools claim that their machines perform the task economically and satisfactorily.

Dentils, modillions, and other enrichments are hand worked.

The operations just described are varied occasionally according to the size of the blocks, the kind of stone, and the capacity of the machines.

It is often more economical to use a machine for a slightly different purpose, in preference to allowing it to stand idle.

In smaller yards, where machinery is not in use, the blocks are sawn under a frame saw manipulated by hand, or in the case of soft limestones, sawn with a cross-cut saw previously described.

Blocks are sometimes split by *wedging* or *coping*.

The " wedge " or " plug " and feathers are used in the granite districts, and the operation consists of drilling a series of holes at regular distances apart, along lines on three sides of the block at which cleavage is to take place. The feathers are then inserted and the wedges driven just tight. A bar of iron is placed under the proposed cope, and the wedges are struck successively with the steel hammer until the block parts.

Many different methods are adopted to cope softer stone, and short punches are used in place of wedges and feathers in practically the same manner as just described (see Fig. 50).

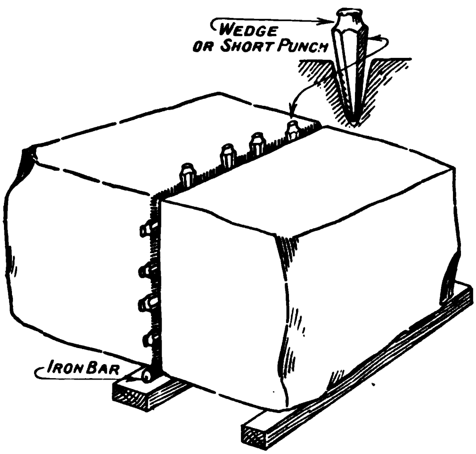


FIG. 50.

In coping slabs of stone or marble a line is drawn on either side of the slab, and a **chasing tool** (a partly dulled hammer-headed tool) of from $1\frac{1}{2}$ to 2 inches wide, is struck with the steel hammer and moved along the line of cope. This starts a fine indiscernible crack on one side. **A coping tool** (a dull hammer-headed tool), or a pitching tool is then used on

the other side of the slab, and struck smartly with the steel hammer until the slab parts in two.

Coping must be carefully executed, and harder blows must be given if the lighter blows are not effective. Much depends upon the structure of the stone and the skill and experience of the mason. Misplaced and hard blows will often break the slab.

The working of any stone must be preceded by the working of a plane surface.

Working a Plane Surface on a Quarry-faced Stone

A straight line may be scribed from A to D (Fig. 51), care being taken that it is sufficiently low to clear cavities and

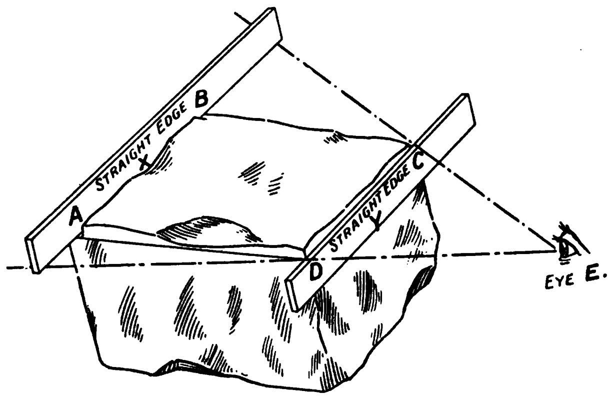


Fig. 51.

indentations in the stone. A straight draft must then be worked along the margin AB, tested with a straight-edge, and re-worked until quite true.

Note.—In working a draft, care must be taken to work **inwards** from each end for a short distance, to avoid spalling the corners of the stone.

Place a straight-edge X on the draft AB, and a second straight-edge Y against the side DC, one end being level with the line AD at D. Raise or lower the end of the straight-edge at C until the top edge of the Y straight-edge coincides with the bottom edge of the straight-edge X by sighting, as shown in Fig. 51.

This operation is termed **boning**, and a line scribed on the stone at the top of straight-edge Y indicates the position of the required draft CD, which must be carefully

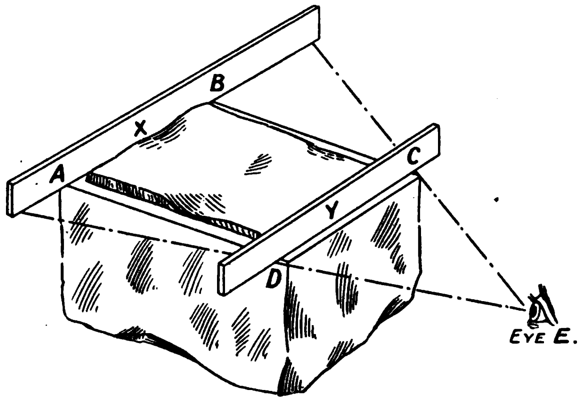


FIG. 52.

worked as before described, and again **boned**, as shown in Fig. 52.

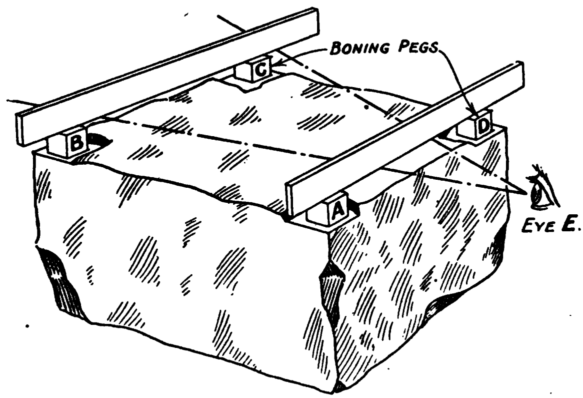


FIG. 53.

The drafts DA, BC may now be worked, and the superfluous stone punched off between the drafts.

A series of drafts worked from DC to AB with claw tool

and boaster, chisel and boaster, or boaster only, according to the freeness of the stone, completes the chisel working of a plane surface.

When a stone is large, it is ofttimes more convenient to use small hard wood cubes of about 2 inch edge, all of the same size, called **boning pegs**.

Make a level sinking at each of the four corners ABCD, and, using two straight-edges, sight along the bottom edges. If this test shows that the pegs are not in the same plane, sink one or other, until the edges of the straight-edges coincide (see Fig. 53). The marginal drafts may then be worked, and the surface reduced and chiselled as previously described.

Guide drafts may be worked across the surface from

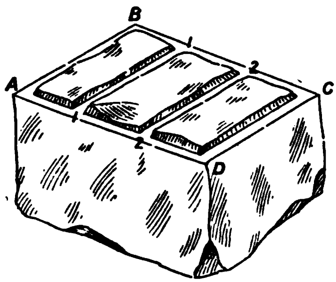


Fig. 54.

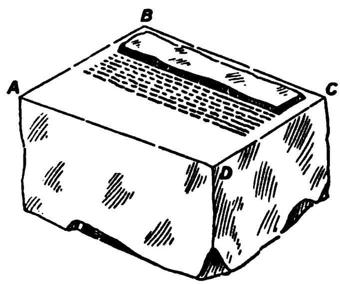


Fig. 55.

margin to margin, as shown in Fig. 54 at 1, 1, and 2, 2; or diagonal guide drafts may be worked from corner to corner, to assist the mason in the accurate working of the surface.

Guide drafts may be and often are dispensed with, the stone being worked as at Fig. 55.

When a surface comes from the saw it may be tested for being in a plane by applying a straight-edge in different directions, lengthways, crossways, and diagonally, and observing whether the edge coincides with the surface in all positions.

Squaring a Surface

A plane surface having been worked, a straight line AD can be scribed on the surface to denote the edge of the surface to be squared and a draft worked to coincide with this line. A second draft must then be worked from D to G,

and carefully tested with the square (see Fig. 56). A third draft may then be worked from A to F and squared from the plane surface, the superfluous stone worked off, as described in the operation of working a plane surface.

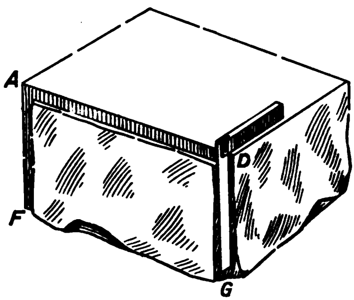


Fig. 56.

In the figure, ADGF, the squared surface, is shown in a vertical position. It is more easily worked when horizontal; but at times joints and surfaces must be worked when in a vertical position, as it is inconvenient to move the stones.

Working a Cylindrical Surface

The ends of the block should be truly squared from the operating surface, and the circular bed moulds scribed on the stone, care being taken to ensure that the axis marked OO′ is at right angles to these beds. This can best be done by drawing a line A*a* on the operating surface, and squaring the lines AB, *ab* on the beds as shown in Fig. 57. The points OO′ can then be measured down from A and *a* and the

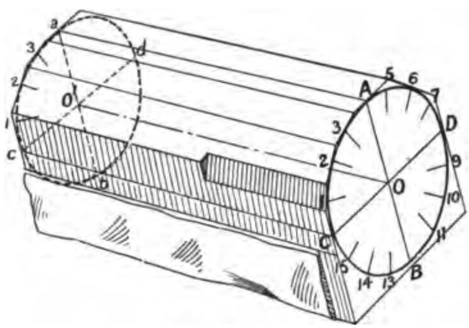


Fig. 57.

lines CD, *cd* scribed on the stone at right angles to AB, *ab*, and preferably boned to insure accuracy. The mould is then applied to these diameters. Rough chamfers may then be punched off the stone, care being taken to see that each chamfer is tangent to the circular mould and *in the same plane*.

In finishing the surface the learner will find it necessary to make frequent use of the straight-edge, and he must take care to apply it along such lines as those shown in the diagram, *e.g.* 1, 1 ; 2, 2, etc.

In applying the moulds to the stone it is preferable to have the letters and numbers on the mould *coinciding at each end of the block,* and to do this, if the lines and figures are showing when scribed at one end, that face of the mould will be against the block at the other end, and the figures and lines hidden ; hence the term **lines up** and **lines down.**

Working a Moulded Surface

A bed should firstly be worked to a plane surface, and the joints worked truly square from the bed. The mould may then be applied to the joints, care being taken that the wall lines WL, *wl,* are square with the bed, and that they lie in the same plane.

The profile may be scribed on the stone as shown in Fig. 58, and the superfluous stone punched away, either in

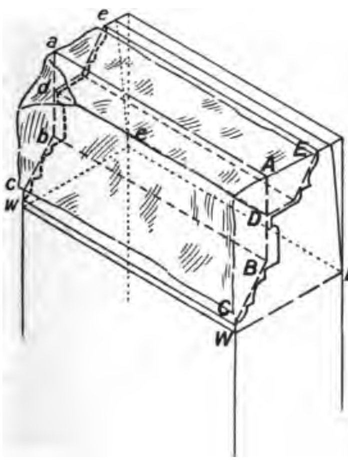


Fig. 58.

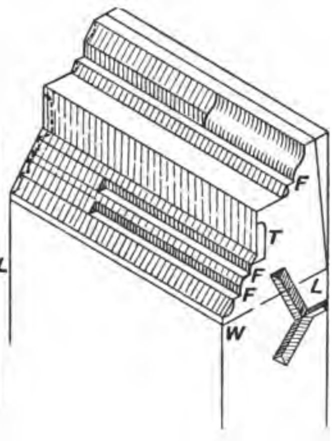


Fig. 59.

the form of large chamfers, or in checks following closely the line of moulding as at EDBC (Fig. 58).

The chamfers can be taken at any convenient position and tangent with as many points of the moulding as is possible

at the discretion of the mason. Smaller checks may then be worked as at FFF in Fig. 59. These checks should be truly worked with the chisel and tested frequently to insure accurate work. Lines scribed on the faces of the rebates coinciding with the arrises of the fillets, enables the mason to stab or incise the stone along the lines to protect the arris from damage. At the same time the lines serve as guides during the operation of working.

The hollow or concave portions of the moulding are worked out with round noses and gouges, sometimes employing the punch or the point as a tool to rough out.

The series of checks and drafts as described, worked accurately from end to end of the stone, is the only way to ensure accurate workmanship, and the young mason will be well advised to adopt this practice.

The operations vary slightly according to the nature of the stone and the size of the mouldings; but the fundamental operations are precisely the same.

In very soft limestones the checks and fillets are sawn by the cross-cut, hand saw, and fillet saw.

Winding or Twisted Surfaces—Ruled Surface

To work a ruled surface, two edges, known as **twist rules** or **winding strips**, are required. The one may be an ordinary

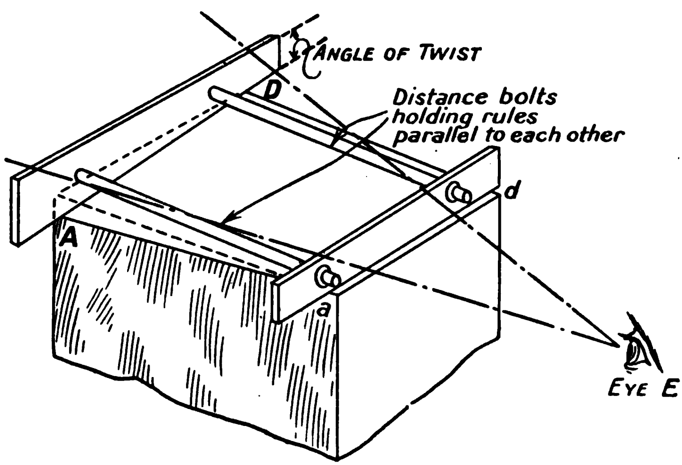


Fig. 60.

parallel straight-edge; the other must contain the angle of twist (see Fig. 60).

Commence by working a draft at each end of the block, and placing one rule on draft AD and the other on *ad*; sight along the top edges, as explained in the operation of working a plane surface, and re-work one or other of the drafts until the top edges of the rules are in one plane.

NOTE.—It is essential that the two rules are parallel with each other during this operation, and the twist rules are sometimes held apart by distance bolts to avoid possible error. Drafts are then worked across the stone from A to *a*, D to *d*, etc., until the surface is complete.

This surface is often used in masonry, and is the nearest mechanical approximation to several correct geometrical surfaces.

SCRIBING A MITRE

When a moulding has been worked through a stone, either by machine or hand-working, and a return moulding has to be cut; it is necessary to draw a line on the moulded surface which will be the intersection of the front and the return moulding. This line is known as a **mitre line**, and the intersecting arrises of the moulding, the **mitre**.

Fig. 61 illustrates a method for obtaining a mitre when the return angle is 90°.

The mitre square is held on the nose of the moulding, the plane of the square being parallel to the bed, the mitre line M*m* on the bed *bisects the angle* of the return. A straight-edge having a true plane face is held on the moulding with the face against the edge of the mitre square. The straight-edge is adjusted until the pencil point when moved along will touch the mitre at M*m* on the bed, and will also touch the arris of the nose adjacent to the mitre square. The straight-edge is thus half the thickness of the pencil distant from the mitre. The mitre line may then be pencilled on to the moulding.

NOTE.—The angle of the mitre square in the example given is 135°, that is—

$$\frac{\text{the return angle}}{2} + \text{a right angle, or } \frac{90}{2} + 90 = 135°.$$

It would be inconvenient to cut a mitre square for angles other than right-angle returns, and the same figure shows another method of scribing a mitre suitable for any angle.

The mitre line M*m* is scribed on the bed, the line bisecting

the return angle as previously described. A square is placed in a perpendicular position on the bed at half the thickness of the

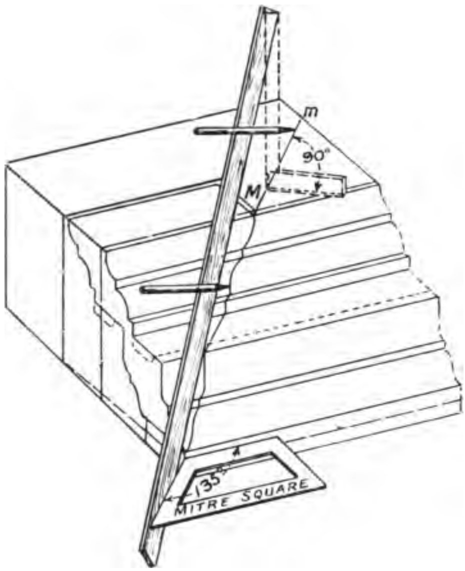


FIG. 61.

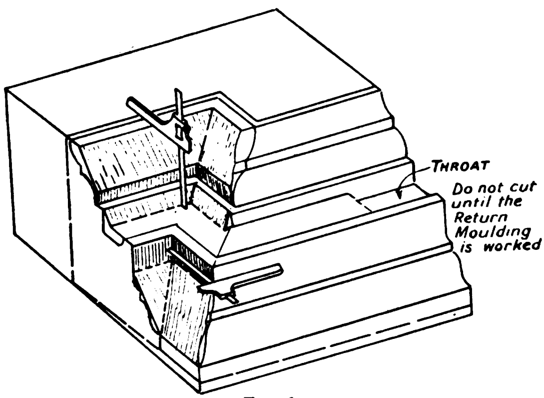


FIG. 62.

pencil over the mitre line, and at 90° to it. The straight-edge is held with the plane face against the blade of the square, and

adjusted until the pencil is made to coincide with the arris of the nose. The mitre can then be drawn on the moulding.

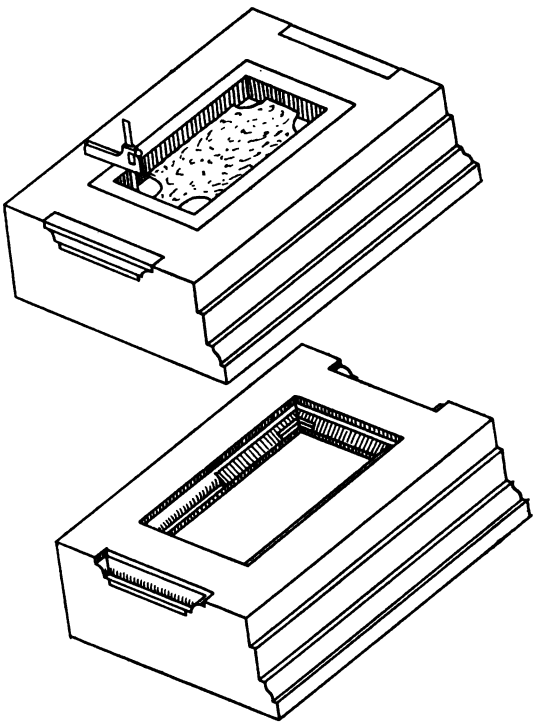
Fig. 62 illustrates the method for working the return, after the mitre has been scribed on the face moulding.

If the moulding returned straight through to the back without an internal angle, it would only be necessary to scribe the mould on the back, and work the return moulding in a similar manner to that described for working a moulded surface.

NOTE.—The working of the throat or any under cut members is the **last operation** to the moulded surface.

SINKING A PANEL

Figs. 63 and 64 illustrate a method for working a panel. The lines of the panel mouldings having been scribed on the



FIGS. 63, 64.

face, sinkings are cut at each corner and tested with the sinking square. The superfluous stone may then be punched away and the panel surface worked in like manner to working a plane surface.

The moulding is worked by working chamfers and rebates as previously described.

In hard stone the chamfer may be worked first with the aid of the shift stock instead of working a square sinking; but in soft stone, where a toothed saw can be used, it is better to sink square with the face.

Working a Pediment Springer

The operation face and bed being worked, the face mould is scribed on the operation surface; and the joints, raking top and return moulding, worked through to the back (Fig. 65). The

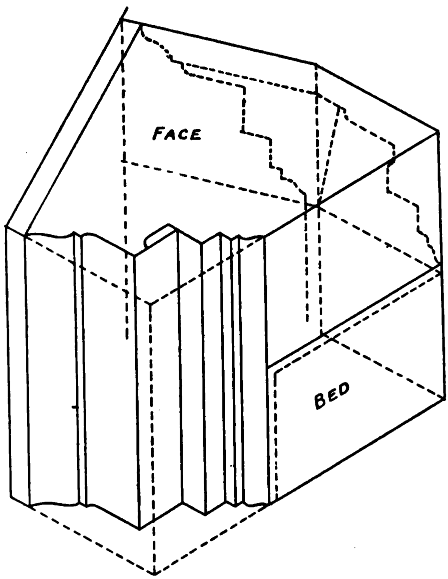


Fig. 65.

joint moulds are then scribed, and the mitre line drawn on the return moulding as previously described.

The raking ogee, the fillet surface AAA, and the horizontal

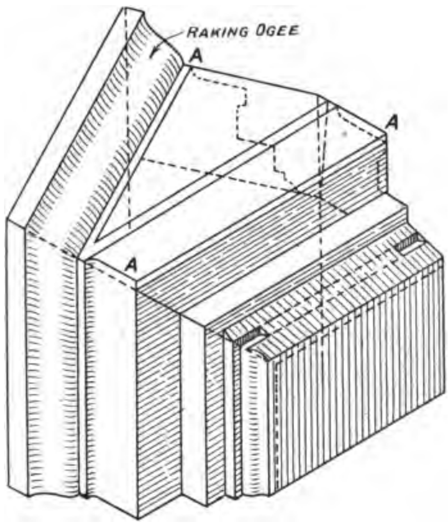


FIG. 66.

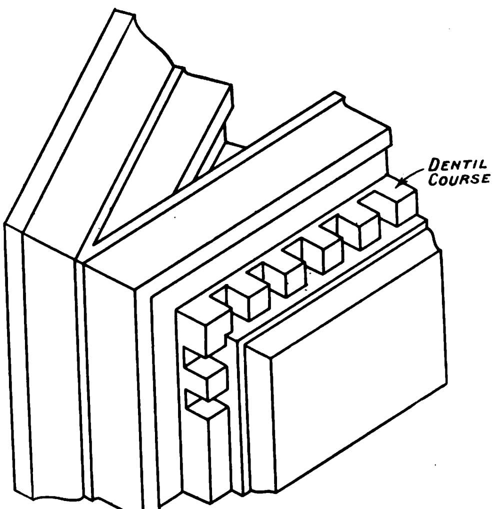


FIG. 67.

moulding is worked in the usual manner from the scribed joint moulding to the mitre line on the return moulding (Fig. 66).

The lower part of the raking moulding must be worked with the aid of the sinking square and shiftstock.

Working the throat is the operation preceding the working of the dentils.

Fig. 67 is a sketch of the completed stone, and if it is held above the head in a diagonal position, the stone will appear as it is fixed on the building.

Cornices with modillions are often worked in two beds, the bed being at the top of the modillions.

When cornices are so high that they must be made in two

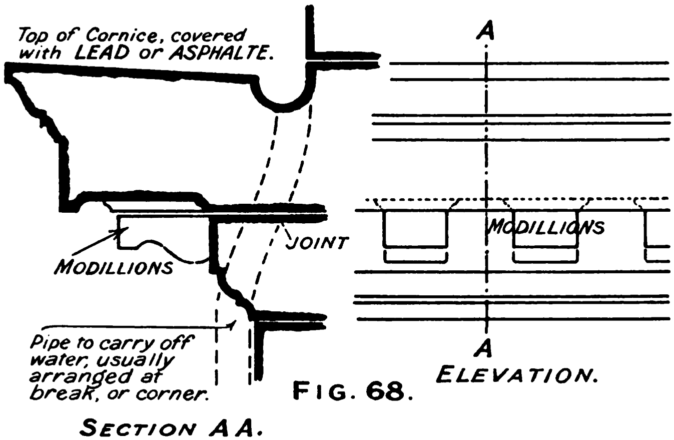


FIG. 68.

or more beds, this is probably the best position in which to place one of the beds. They have, however, an economic value, as it is easier to fret the modillions than to cut them from the solid (see Fig. 68).

Working an Octagon Cap

The bed being worked, the bed mould is scribed on the stone and four operation faces squared sufficient to apply the raking mould (Fig. 69). The moulding is then worked to four sides and mitre lines drawn on the mouldings to enable the mason to complete the cap. (The mitre square of 135° cannot be used

for these mitres, and the second method previously described must be adopted.)

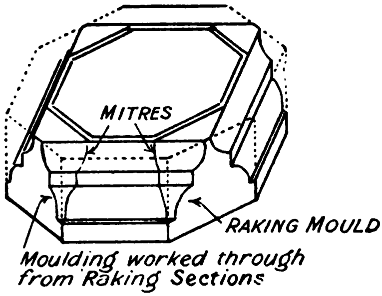


FIG. 69.

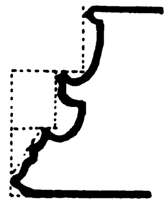


FIG. 70.

It is sometimes more convenient and economical, especially in Gothic architecture, to work the cap by means of square sinkings from the bottom bed (see Fig. 70).

CHAPTER III

DRAWING AND SETTING-OUT

THE setter-out should have several large boards at his disposal to enable him to draw and set out the work to full size, and they may be fixed either horizontal or vertical.

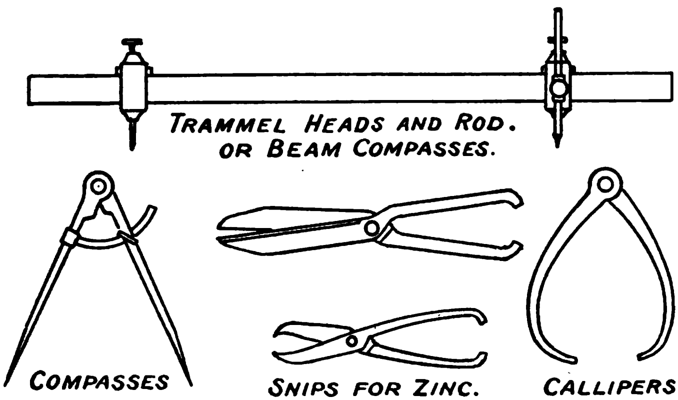


FIG. 71.

Pipe clay[1] is mostly used for cleaning off the old lines, and whitening the board.

Five feet and two feet rules. Several good straight-edges. One or two good set squares.

A pair of trammel heads, and rods of varying length to fit same.

A pair of compasses and dividers.

A few steel scribers and bradawls.

[1] A good water paint is a very satisfactory material for whitening setting-out boards.

Some deal rods for storey rods, gauge rods, and for setting out lengths of cornices, modillions, and dentils.

Two or three pairs of good shears or snips for cutting zinc, and some small smooth cut files for filing the moulds to shape, with callipers, comprise the most important tools for the setter-out.

Experience will teach him that many tools can be made that will be of great service, and some setters-out pride themselves in the little tools they have collected from time to time in setting out intricate work.

Mouldings

The design of mouldings is perhaps not strictly the vocation of the mason, but it is included in the syllabus of the City and Guilds of London Institute, and if only for this reason, justifies its inclusion in this book.

Classic Mouldings

The **cyma recta** (Fig. 72), a double curved moulding, formed in the figure by two quadrants of circles, having their centres on the same horizontal line AB.

Fig. 73 shows a method for finding the centres of arcs of circles C1, C2, when the projection is not the same as the height.

Join AB and bisect AB in D, bisect AD and DB, and these bisection lines meet the perpendiculars from A and B at C1 and C2 respectively, which are the centres from which to describe the arcs forming the moulding.

It is not essential that the arcs forming this moulding should be of equal radii, in which case the common normal C1, D, C2 may be raised or lowered to suit. The centres C1, C2 may be taken at any convenient distance along the perpendicular bisectors of AD and BD.

The Grecian designers invariably formed their mouldings of the segment of some conic section, and Fig. 74 shows a method of describing a cyma recta formed of two parabolic curves. The horizontal line O6, is divided into an even number of equal parts, and vertical lines are drawn through these divisions.

The vertical line O6 is divided into the same number of equal parts and numbered as shown. From A join 1 and 2, and from B join 4 and 5. These lines cut the corresponding vertical lines at points in the curve, and a fair freehand line completes the drawing.

Cavetto (Fig. 75). A hollow moulding formed of the quadrant of a circle.

Fig. 76 shows a method for describing the Greek cavetto

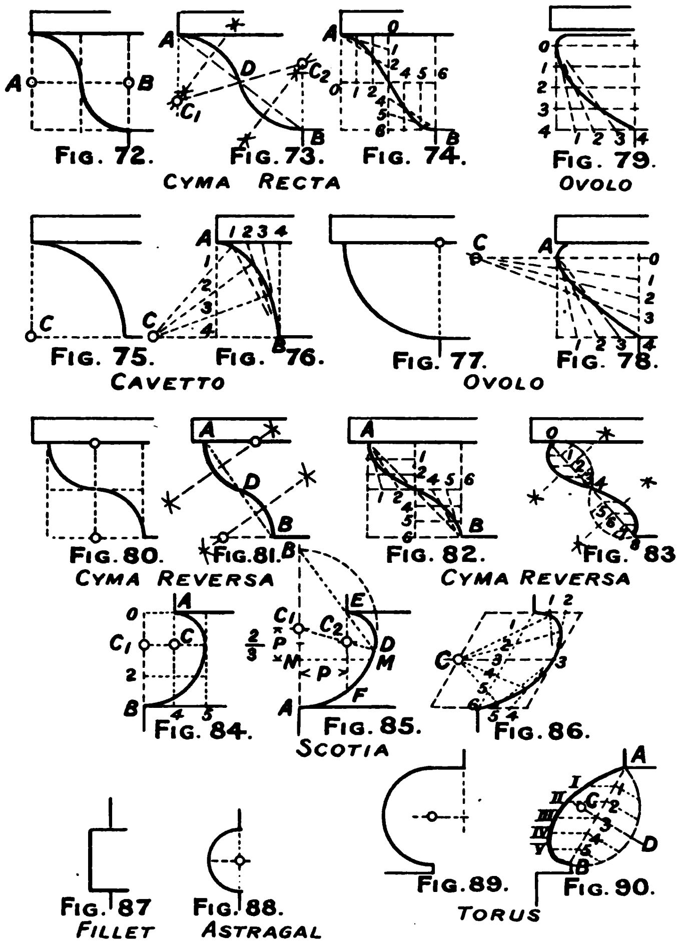


FIG. 72. FIG. 73. FIG. 74. CYMA RECTA FIG. 79. OVOLO

FIG. 75. FIG. 76. CAVETTO FIG. 77. FIG. 78. OVOLO

FIG. 80. FIG. 81. CYMA REVERSA FIG. 82. FIG. 83. CYMA REVERSA

FIG. 84. FIG. 85. SCOTIA FIG. 86.

FIG. 87 FILLET FIG. 88. ASTRAGAL FIG. 89. FIG. 90. TORUS

as the quadrant of an ellipse. Divide the height A4 into an equal number of parts, and the projection A4 into the same number of equal parts; make C4 equal to the projection 4B. Draw lines from 1–2 and 3 to B, and from C draw lines through

the vertical division 1–2–3. These lines cut the corresponding lines at points in the curve.

Ovolo or **Echimus** (Fig. 77). A quadrant of a circle in the Roman example. A segment of a conic section in the Greek.

Fig. 78 shows the ovolo described as a hyperbolic curve.

Fig. 79 shows a parabolic curve. In Fig. 78 CA is made equal to AO, and the divisions are made and lines drawn as before described.

Cyma Reversa (Fig. 80) or ogee is the reverse of the cyma recta. In the Roman example the centres of the quadrants of the circles are on the vertical line.

Fig. 81 shows a less projection, and the centres may be found in the same manner as described for the cyma recta (Fig. 73).

Fig. 82 shows a Grecian ogee formed of parabolic curves, and the student may follow the instructions for describing the cyma recta (Fig. 74).

Fig. 83 shows another method where these curves are portions of ellipses. Follow the method described for Fig. 90.

Scotia or **Trochilus** (Fig. 84). A base mould, the height is divided into three; the top or smaller quadrant is described from C, one-third the height. C1B is equal to two-thirds the height, and C1 is the centre of the larger quadrant.

Fig. 85 shows a method for describing the moulding by means of arcs of circles. E is the top of the curve, and A the extreme projection. Draw verticals AB and EF as shown. The distances between these two vertical lines is P the projection. The line NM is a horizontal line bisecting the height: make NC1 equal to two-thirds of P, and from C1 describe the semicircle ADB. Draw a line from B through E to the semicircle at D; join DC1, and this line crosses the perpendicular line EF in C2, the centre of the smaller arc DE.

Fig. 86 shows the Grecian scotia formed of a portion of the ellipse. C3, equals 3,3, and the method for describing the curve is similar to that described for Fig. 76.

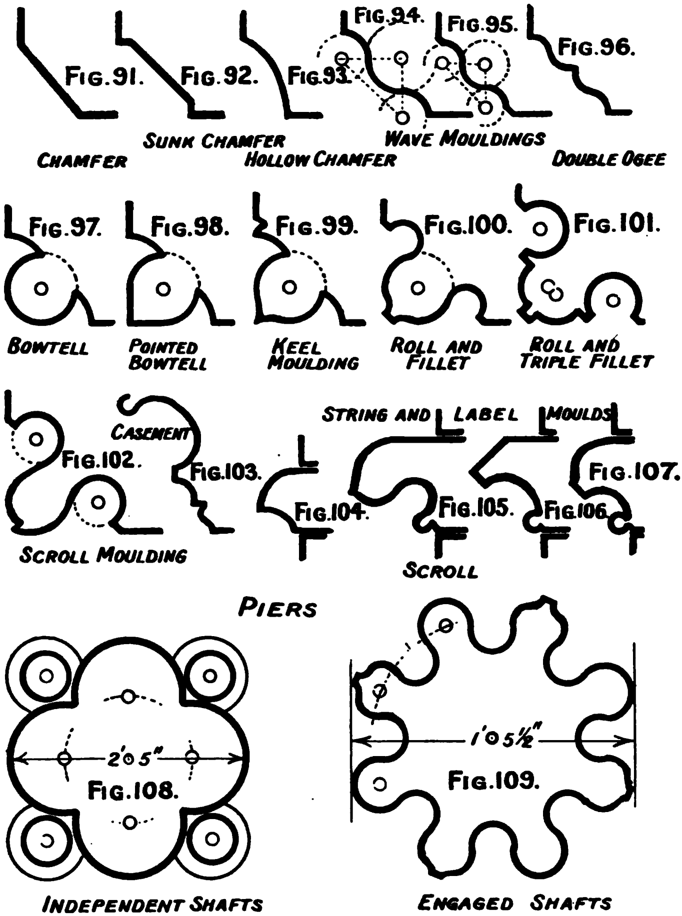
Fillet or **Listel** (Fig. 87). A flat band used to divide other mouldings.

Astragal or Bead (Fig. 88). A small semicircular moulding.

Torus (Fig. 89). A base moulding, semicircular in the Roman example with a quirk below.

Fig. 90 shows an example with an ellipse curve. Draw a line AB from the top of the mould to the quirk at the bottom, and describe an arc of a circle from any centre C; divide AB

into a number of parts and project at right angles from AB to the arc of the circle. From the same points project horizontal



lines and make these lines equal to the projector lines 1, 2, 3, etc., as at I, II, III, etc.

The segment ADB may be of greater or less rise than the examples, in which case the moulding will be fuller or flatter.

Gothie mouldings are illustrated in Figs. 91 to 107, and need

little description. They are separate members that are assembled to make a complete moulding, and the student who desires to correctly design Gothic mouldings should consult those books that are written specially on this subject. He should also study examples of mediæval work.

Figs. 108 and 109 show plans of two piers to different scale. Fig. 108 is the plan of a pier with independent shafts. Fig. 109 shows a plan of pier with engaged shafts.

Enlarging and Reducing Mouldings

ADEB (Fig. 110) is a parallelogram enclosing a given moulding to be enlarged to three times its size. This may be done by **radial projection.**

Produce the base line BE in both directions, and at any convenient distance erect a perpendicular *ab*, making it three times the length of AB. Through A*a* draw a line until it intersects the base line at P (**the polar point**). Draw *ad* parallel to the base line, and from P draw a projector PD until it cuts this line at *d*; a perpendicular *de* completes the enlarged parallelogram.

The cavetto and ovolo mouldings in the example are arcs of circles described from centres C1, C2.

Join these points by a horizontal line, and from P through C1 draw a line until it intersects *ab* at *c*1, the centre from which to describe the cavetto.

A radial drawn from P through N will intersect *ab* at *n*, and *c*1.*n* is the radius of the cavetto.

Through *c*1 draw a parallel to the base line: the centre of the ovolo lies on this line.

A line from P through C2 intersects the parallel at *c*2, the centre for describing the ovolo.

As this line intersects the parallel in an acute angle it is better to erect a perpendicular from C2 to F, and a radial drawn through PF will intersect *ad* in *f*, from which a perpendicular may be drawn until it meets the parallel at *c*2, the required centre.

All other points may be found in a similar manner.

If the curves were not arcs of circles, it would be necessary to take a series of points in the curve as at XY, erect perpendiculars until they cut AD in 1 and 2. From P through 1 and 2 draw lines until they meet *ad* in I, II. Radials from XY will intersect perpendiculars from I, II at *x*, *y*, which are points in the curve.

Only two points are shown in the example, but it may be necessary to take others to ensure accuracy.

It is sometimes necessary to enlarge mouldings in only one direction.

Fig. 111 illustrates a cavetto moulding enlarged to twice its height, the projection remaining the same.

ABDC is a parallelogram enclosing the given moulding. AB*dc* a parallelogram twice the height but of the same width to enclose the required moulding. Assume any polar point P on the line AB produced, and draw a line *d*P. From D draw a parallel to AP until it intersects *d*P in *d*1, and erect a perpendicular *d*1 *b*1.

N is a point on the given curve. From N draw a horizontal line until it meets *b*1 *d*1 at N1; from P through N1 draw a line meeting B*d* at *n*1. A horizontal line from *n*1 will intersect a vertical line from N at *n*, a point in the required curve.

Other points may be taken in the same manner.

The curve ENF in the example is the quadrant of a circle, and the curve *enf* is therefore the quadrant of an ellipse by projection.

Fig. 112 shows a method for enlarging a moulding, the projection being of different proportion to the height. In the example the projection is increased by one-third and the height doubled.

ABDC is the given moulding. Make *a*B one-third larger than AB, and make B*d* twice BD. Two polar points are necessary, P1 and P2, which may be at any convenient points on AB and *d*B produced.

Join *d* P1, and draw a horizontal from D to *d*1 and a perpendicular from *d*1 to *b*1. Draw a line from *a* to P2, and a vertical line from A to *a*2. Through *a*2 draw a line parallel to *a*B as at *a*2 *b*2.

N is a point on the given curve: from N draw perpendicular and horizontal lines to N2 and N1, and from P1 P2 draw radials through N1 N2 to *n*1 *n*2.

Horizontal and perpendicular lines from *n*1 *n*2 will intersect at *n*, a point on the required curve. Any number of points may be found in a similar manner.

Raking Moulds

Fig. 113 shows a portion of the moulding of a pediment.

A1 to G1 shows the contour of the return horizontal

moulding. Take any number of points on the curve as at

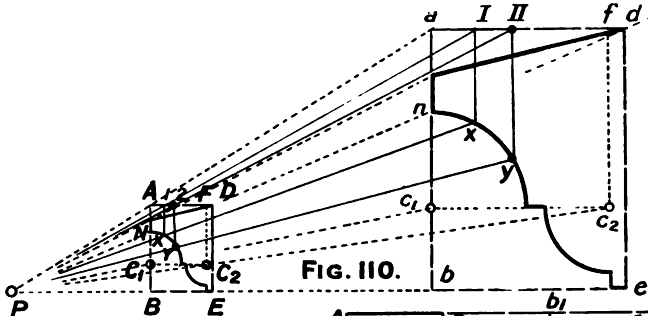


FIG. 110.

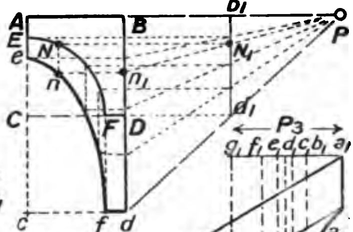


FIG. 111.

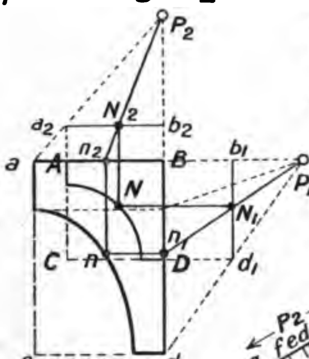


FIG. 112.

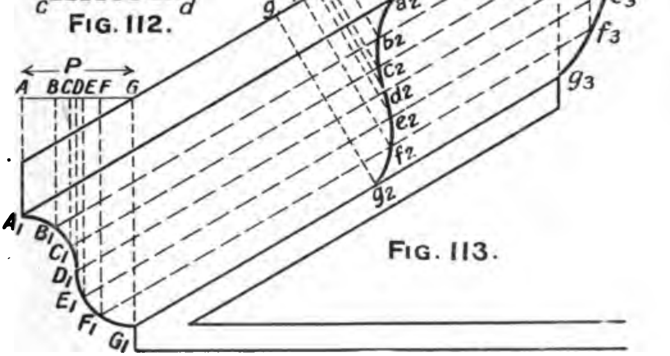



FIG. 113.

B1, C1, D1, etc., and project perpendiculars to A, B, C, D, etc., P being the projection of the moulding from the fillet. This

projection remains constant, but in the raking moulding the height is considerably increased.

Through the points B1, C1, etc., draw lines parallel to the slope of the pediment, and draw any line *g g2* at right angles to these lines; make P2 equal P, the projection of the moulding, and make *gfed*, etc., equal to GFED, etc. Parallel lines to *g g2* through *fed* will intersect the raking lines at *f2*, *e2*, *d2*, etc., and a fair line drawn through these points will give the required raking section. (See description for working a pediment springer, p. 26.)

In a broken pediment another raking mould is required, the projection P3 being equal to P. A careful examination of the illustration should enable the student to obtain this mould.

Fig. 114 shows an example of a curved pediment, and in this case the parallel lines are concentric arcs of circles, and the line *g g2* is a normal to the curves (*e.g.* a line converging to the centre from which the arcs were described). The concentric circles meet the line *g g2* in B2, C2, D2, etc., and the lines B2 *b2* and C2 *c2*, etc., ***must be at right angles*** to this line. The points *g*, *f*, *e*, *d*, *c*, *b*, *a* must be measured as before described on a line at right angles to *g g2*, and lines parallel to *g g2* through these points, will intersect the lines at right angles to *g g2* at *a2*, *b2*, *c2*, *d2*, *e2*, *f2*, which are points in the required curve.

An inspection of the illustration should enable the reader to describe the moulding for a broken pediment.

NOTE.—The points *g3*, *f3*, *e3*, etc., in the required moulding, are at the intersection of vertical lines from *g1*, *f1*, *e1*, etc., and the concentric arcs from G1, F1, E1, etc.

RAKING MOULD AT OBTUSE OR ACUTE ANGLE

Two walls (Fig. 115) meet at an angle of 135°, and it is desired to cut a template that will apply on the face O*b*. The required section is thus an elongated or raking section.

AB*b*ONM is a plan of the stone, AB being the joint and X the normal section. Take any number of points in this section as at C, D, E, F, etc., and draw parallels to the top bed until they cut the wall line AM1 at points 1, 2, 3, 4, etc. From the same points draw parallels to the nose line B*b* in plan, until they intersect the face O*b*, and draw lines at right angles

to O*b*. Measure the points 1, 2, 3, 4, etc., on line AM1, and transfer them to *am* as at I, II, III, IV, etc.

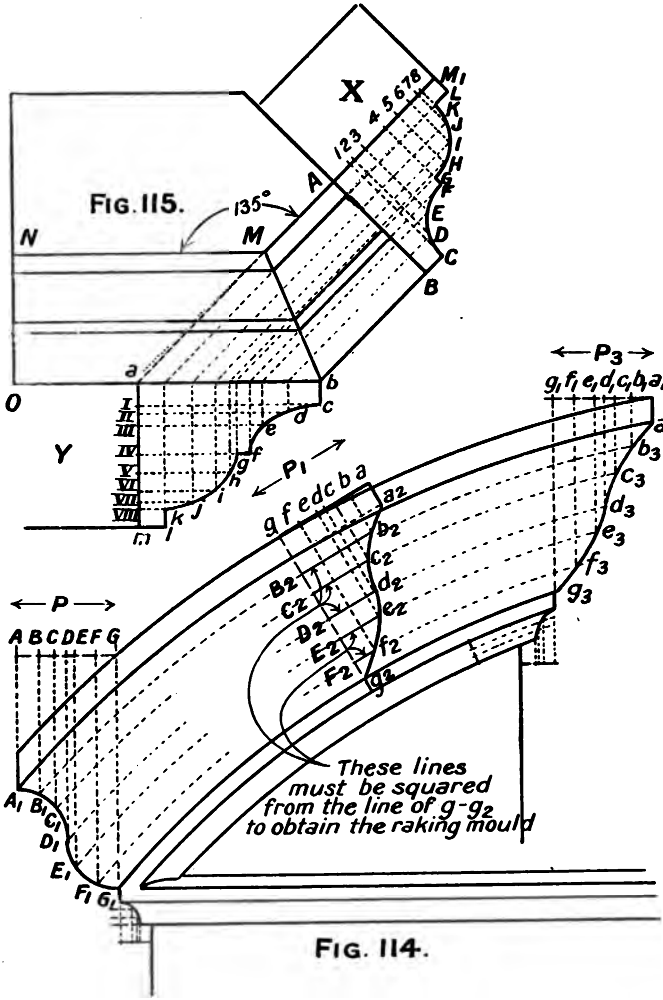


FIG. 115.

FIG. 114.

Parallels to the line O*b* from these points will intersect the vertical ordinates at *c*, *d*, *e*, *f*, etc., at points in the required curve.

Entasis of a Column

The **entasis** is the swell or camber that is worked on a classic column, to obviate the optical illusion that is experienced when looking upwards at cylindrical columns.

The ancients made the upper diameter of the column smaller than the lower, and these diameters are known as the inferior and superior respectively. This difference is much exaggerated in the examples, so as to more clearly demonstrate the methods. In actual practice the difference is not great.

The entasis may commence from the bottom of the column, or any distance up from the bottom; in any case the methods would not differ from those described.

Fig. 116 shows a method for setting out the entasis.

BO is half the superior diameter and DC half the infeiior. NM is the centre line. The entasis commences from one-third the way up the column. With O as centre and BO as radius describe a semicircle; draw a perpendicular from D to the semicircle at F, and draw the horizontal chord F*d*. Divide *d*O into a number of equal parts as at 1, 2 3, and draw parallels to F*d* until they meet the semicircle at 1, 2, 3. Divide the height CO into the same number of equal parts as at I, II, III, and draw horizontals through the points.

Erect perpendiculars from 1, 2, 3 on the semicircle until they cut the horizontals from I, II, III, the intersection of the lines being points in the curve.

NOTE.—The more divisions that are taken, the more exact will be the curve. A lath or rod that will bend may be used to draw the line through the points.

Fig. 117 shows a mechanical method for describing the entasis.

The centre line MN is first drawn, and the line BOP, from which the entasis starts, is drawn at right angles.

BO is half the superior diameter and DC half the inferior diameter. With centre D and radius equal to BO (half the superior diameter) mark off E on the centre line; from D through E draw a line to meet the horizontal line in P.

A grooved rod (see Fig. 118) is fixed on the centre line to receive a pin *f* (about ½-inch diameter) that will move freely along the groove. A second rod *dp* slotted at the bottom end is required for the trammel. A peg about ⅜-inch diameter is fixed to the board at P, the slot in the trammel being of

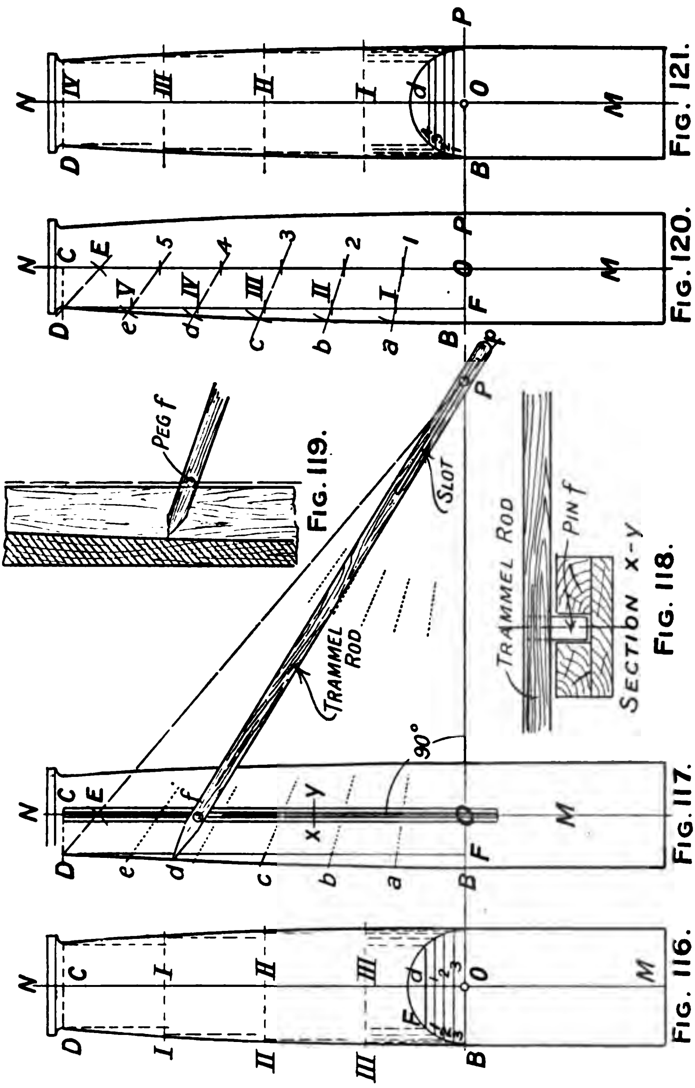


FIG. 116. FIG. 117. FIG. 118. FIG. 119. FIG. 120. FIG. 121.

sufficient width to allow of free sliding without side play. The peg at *f* slides in the vertical groove, and *d* is the pencil point; *df* equalling half the superior diameter.

Starting with the trammel over the line DEP, and sliding the peg *f* down the vertical groove, whilst the slot in the trammel slides along the fixed peg P, the pencil point *d* on the trammel will describe the curve. This curve is known as the **concoid of Nicomedes,** and is the curve that is generally used for the entasis of columns.

NOTE.—The centre grooved rod may be dispensed with if a board is used with one edge planed. In this case the board should be about three inches wider than half the column, the planed edge should be placed at half the thickness of the peg *f* from the centre line (see Fig. 119), and the board fixed to the setting-out board. The setting out will be followed as already described, and after the conchoid is drawn on the board it can be cut, and that portion shown hatched in the diagram may be used by the mason as a template for working the stone.

The mechanical method just described would be found too cumbersome for large columns, and Fig. 120 shows a method for describing the conchoidal entasis for large columns, or where the setting-out space is limited.

Commence by drawing the centre line NM and a line BOP at right angles from which the entasis commences.

BO is half the superior diameter, DC is half the inferior diameter.

Find the point E as described in the previous example, and divide EO into any number of equal parts, as at 1, 2, 3, etc. Divide DF, which is parallel to the centre line, and half the inferior diameter from it, into the same number of equal parts, as at I, II, III, etc.

Join I1, II2, III3, etc., and make 1*a* equal OB, 2*b* equal OB, 3*c* equal OB, etc., which is in all cases half the superior diameter. A fair line drawn through these points will describe the curve.

Observe that the lines DE, *e*5, *d*4, etc., are positions of the trammel rod described in the previous example.

Fig. 121 shows another method for describing the entasis. Draw the centre line NM and the line BOP at right angles to it, as before. BO is half the superior diameter, D IV half the inferior diameter.

With centre O, radius BO, describe the semicircle B*d*P; from D draw a line parallel to the centre line until it intersects

the semicircle at 4. Divide the arc 4B into any number of equal parts by pricking over with the dividers as at 1, 2, 3, 4, and divide the centre line O IV into the same number of equal parts as at I, II, III. Draw horizontal lines through these points, and vertical lines through 1, 2, 3 until they intersect the corresponding horizontal lines, the intersections being points in the curve through which a fair line may be drawn.

Arches

Definition.—The arch is an arrangement of wedge-shaped blocks, to cover an opening in a wall. Each block is kept in position by pressure against the next, and the end or lower blocks are supported by the abutments.

The blocks forming the arch (Fig. 122) are known as **voussoirs**, and the lowest ones—*e.g.* those next the abutments—are called **springers**, whilst the centre or apex block is the **keystone**.

The top of the arch containing the keystone is the **crown**, and the **haunch** lies between the crown and springers.

The **intrados** or **soffit** is the underside of the arch, whilst the upper or convex surface is the **extrados**.

The **skewback** is the sloping abutment against which the springer in a segment or straight arch rests (see Fig. 137).

The **span** is the horizontal distance between the abutments.

The **Rise** is the vertical distance measured from the springing line to the crown of the intrados (see Fig. 123.)

Springing points are the points from which the intrados of the arch commences to curve from the abutment.

Fig. 122 is a **semi-arch**, the intrados and extrados being semicircles described from the centre C, which lies on the springing line, midway between the springing points AB.

The bed joints of the arch all converge to the centre C.

Fig. 123 is a **segment arch**, AB span, OD rise. Draw a line from A to D and bisect.

The bisection line intersects the centre line at C, the centre from which the circular arc may be drawn.

The arch shown in this figure is said to be **stilted**, as the springers have a vertical upstand between the caps and the springing line.

Figs. 124, 127 show two **lintels** with joggle joints.

Fig. 126 shows a **straight** or **camber arch** having joggled joints. The arch should have a slight camber or curve, about

⅛ inch to every foot of span. The rise in the example would be $\frac{19}{32}$ inch.

Joggled joints, as shown in Figs. 124, 126, 127, are now used chiefly for terra cotta buildings.

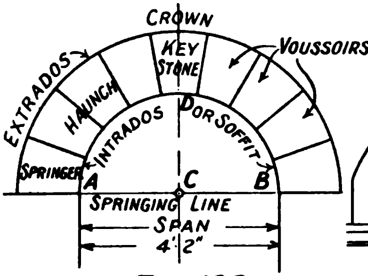


FIG. 122.

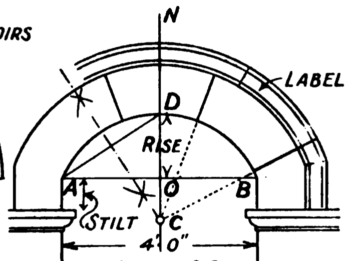


FIG. 123.

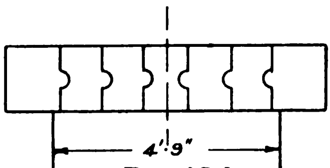


FIG. 124.

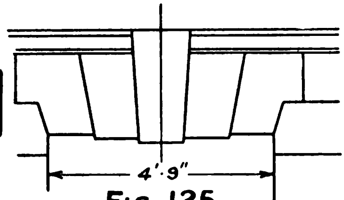


FIG. 125.

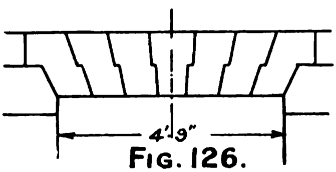


FIG. 126.

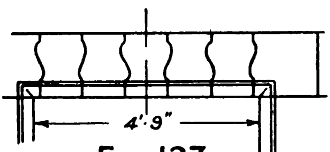


FIG. 127.

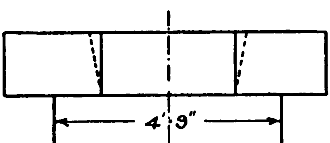


FIG. 128.

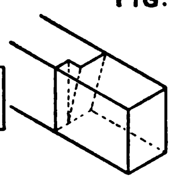


FIG. 129.

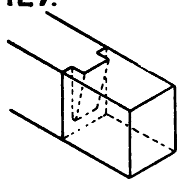


FIG. 130

Terra cotta is more effective when made in small blocks, and the joints therefore lend themselves to terra cotta construction.

Fig. 125 shows an arch with a falling soffit and projecting keystone; no special description is needed for this simple drawing.

Fig. 128 shows a lintel in three stones with secret joggle joints. By this method a vertical joint is shown on the face, and the back portion is splayed so as to form arched joints (see Fig. 129).

Another illustration of a secret joggle is shown in Fig. 130. In this example the end stones are recessed, and the centre stone is worked with a splayed projection to fit into the recess, thus forming the secret arch. This form of joint is used in lintels over porticos, or in positions where the stone is seen on both sides.

Fig. 131 shows an **Equilateral** pointed arch, so called as the springing points and the crown of the intrados if joined by straight lines, would form an equilateral triangle.

Very little description is necessary to draw the arch. A and B are the springing points, and are also the centres from which the arch is described. When pricking over the voussoirs it is better to draw a centre line (shown dotted) and prick over this line to decide the bed joints, and thus avoid too large a stone at the crown.

Fig. 132 shows an **Acute** or **Lancet** arch; the centres in this instance are outside the springing points, but are on the springing line.

AB is the span, OD the rise; join AD by a straight line and bisect. The bisection line meets the springing line at the point C1, which is the centre from which the arch is drawn. C2 is measured from O, making OC2 equal OC1.

Fig. 133 is an **Obtuse** or **Drop** arch. The centres are on the springing line, but inside the springing points AB. The centres may be found in the same manner as the acute arch.

The bed joints in this example are shown converging to the centre of the springing line O.

Where bed joints do not converge to the centre from which the arc is described, the arch is known as a **scheme.**

NOTE.—The best construction is for the joints to converge to the respective centres from which the arcs forming the arch are drawn—

1, 2, 3, 4, converging to C.
5, 6, 7, 8, converging to C1.

Fig. 134 shows a **Drop Arch** with centres below the springing line. AB is the span, OD the rise. Join AD and bisect.

Any point C1 on the bisection line, and on the opposite side of the centre line, may be a centre from which the soffit may be drawn through the points AD.

If two nails are fixed to a board at A and B (Fig. 135), the

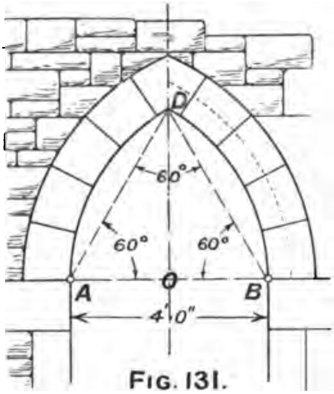


FIG. 131.

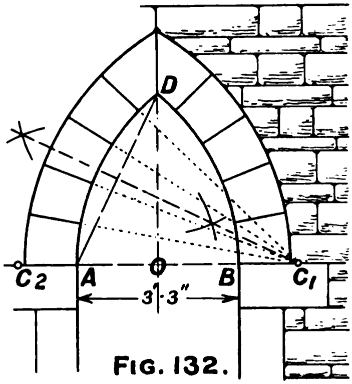


FIG. 132.

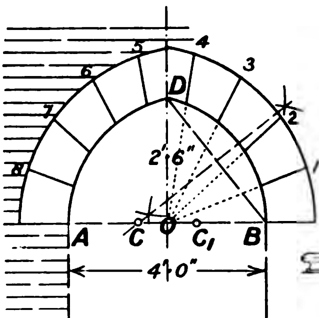


FIG. 133.

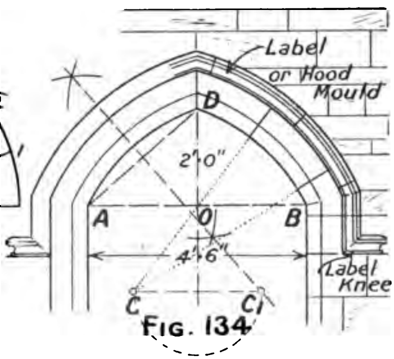


FIG. 134.

Scale 12 9 6 3 0 1 2 3 4 5 6 7 8 9 of Feet

angle of a square *e*, its blade sliding along nail B and its stock sliding along A, will describe a semicircle.

In the segment of a circle ADB (Fig. 136), lines drawn from A and B, the extremities of the chord, to any point in

the arc, will be found to have the angles between them constant, that is ACB, ADB, and AEB are all equal to one another.

The above property may be applied to setting out a segment arch where the centre is inaccessible.

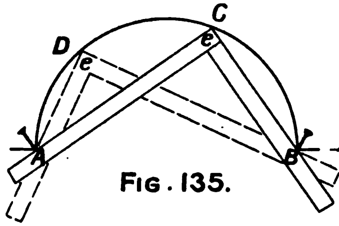


FIG. 135.

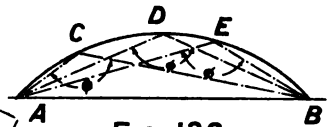


FIG. 136.

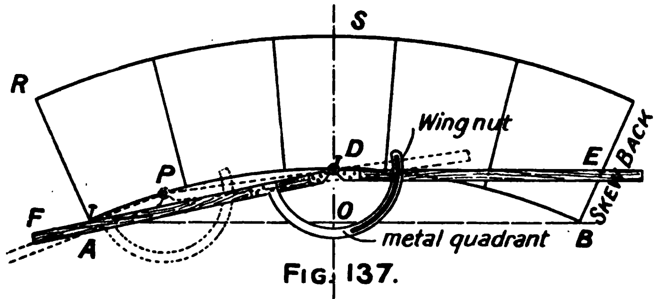


FIG. 137.

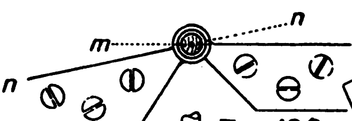


FIG. 138.

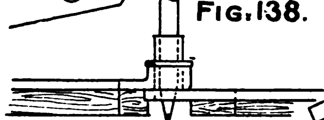


FIG. 139.

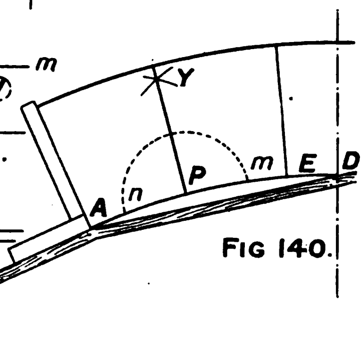


FIG 140.

Fig. 137 illustrates a tool for drawing such arches.

Two laths of hard wood with straight edges are required, with a sleeved metal hinge for holding the pencil (see Figs. 138, 139), and a metal quadrant and wing nut. The centre of the

pencil must be at the intersection of the two lines *nn*, *mm* (Fig 138).

To describe the arch (Fig. 137), AB is the span, OD the rise. Fix a nail through the pencil sleeve as at D and place the edge of the lath FD against the nail A; open the tool until the edge DE is parallel to the springing line AB, and fix in this position with the quadrant and wing nut.

When fixed at this angle, if the edge of one lath slides along the nail A whilst the edge of the other lath slides along the nail D the pencil P will describe the required curve. The dotted line shows the tool in another position.

If the extrados of the arch is concentric with the intrados, the same tool, at the same angle, but with nails at R and S, will describe the curve.

To draw the joints divide the intrados in the usual way, and with any convenient distance in your compasses draw the arc *n*P*m* (Fig. 140) and bisect with two intersecting arcs, as at Y.

To draw the skewback, set the tool with the angle at A, the springing point, and the edge E passing through D at the crown; a square on the edge FA will give the skewback.

NOTE.—Strips of wood made up to form a triangle would give the same result (see Fig. 141).

The radius may be found by calculation, and is specially useful when plotting large circular arcs (see Fig. 142).

A = versed sine

B = half the chord

$$\text{radius} = \frac{B^2 + A^2}{2A} = \frac{9^2 + 4^2}{2 \times 4} = \frac{81 + 16}{8} = \frac{97}{8} = 12{\cdot}125 = 12'\ 1\tfrac{1}{2}''\ \text{radius}$$

Fig. 143 shows an arch described from three centres, AB being the span, OD the rise.

Draw a straight line from D to B, and with O as centre and OB radius describe a quadrant of a circle meeting the centre at E. Make DF on the line DB equal to DE, and bisect the remainder of the line FB. The bisection line intersects the springing line at C2 and the centre line at C1; these are two of the required centres. The bisection line is the common normal of the two circular arcs, which are tangential at T and G. The centre C3 may be found by measurement.

To avoid inequality in the size of the voussoirs it is better to step off on a line midway between the intrados

and the extrados; this line is shown dotted in the diagram HE.

The bedding joints are drawn from the respective centres from which the arcs of the circles forming the curve are drawn.

It is not always convenient to use the above method, and

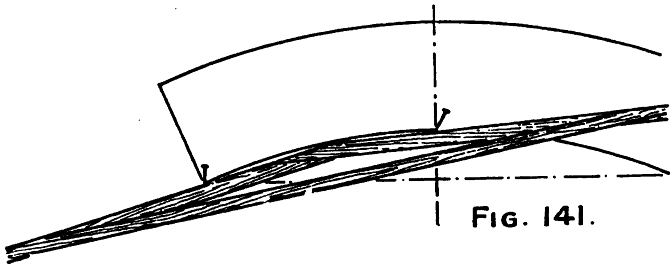


FIG. 141.

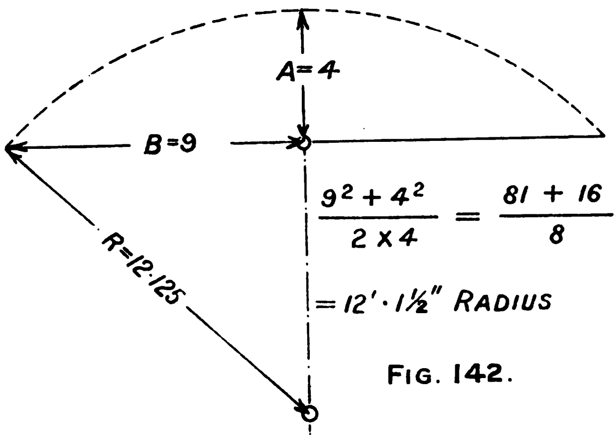


FIG. 142.

Fig. 144 shows another method for obtaining an arch formed of arcs of circles drawn from three centres.

In this case the span AB and the rise OD are given, and also the radius of the smaller arcs, *e.g.* C2B=9 inches. This distance is marked off on the centre line at C4 from D. C4 and C2 are joined by a straight line, and the line bisected. This bisection line intersects the centre line in C1, which is the required centre. The centres must be joined by straight lines as shown, C1M, C1N, which are the common normals

where the arcs of the circles forming the arch are tangent. It will be seen from the drawing that centre lines, shown by

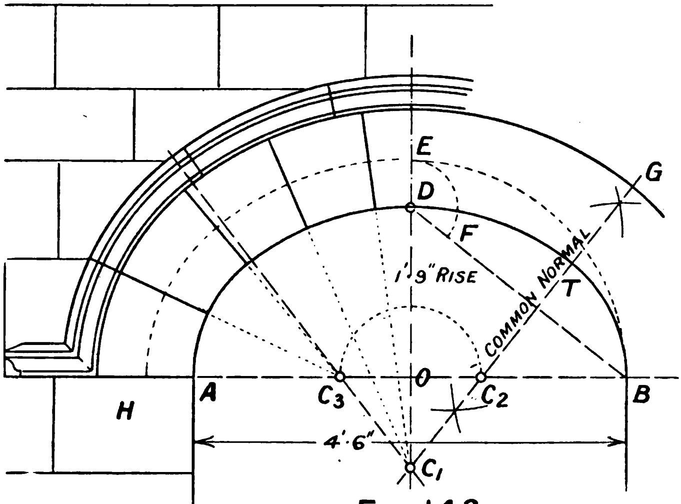


FIG. 143.

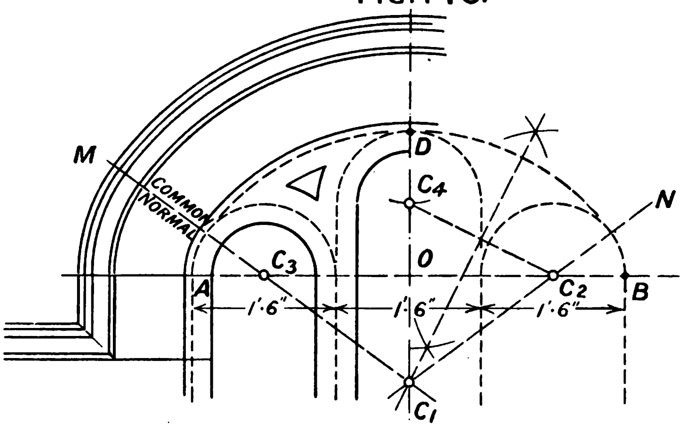


FIG. 144.

Scale 12 6 0 1 2 3 4 *of Feet*

dotted lines, have been used in this example instead of the clear span used in Fig. 143.

Approximation to a Semi-Ellipse Arch from Arcs of Circles

Fig. 145 shows a method of drawing a curve approximating an ellipse by arcs of circles. It consists of finding points in the ellipse curve and drawing arcs of circles to pass through the points.

The drawing illustrates the arch drawn from five centres; but seven, nine, or any odd number of centres may be found in the same way.

AB is the span, OD the rise; from D draw a line DF parallel to the springing line, and from B draw a perpendicular line intersecting the first line at F. Make OE equal to OD, divide[1] BF into three equal parts, as at 1 and 2, and divide OB into the same number of equal parts, as at I, II.

Draw straight lines from 1 and 2 to D, and lines from E through I and II until they meet the former at XY. D, Y, X and B are points in the ellipse, and the bisection line of DY will pass through the centre line at C1.

A line joining C1, Y is a common normal, and the first portion of the curve may be drawn from centre C1 to this common normal C1N. XY may now be bisected, and the bisection line will intersect the common normal C1N in C2. With centre C2 and radius C2Y a circular arc may be drawn passing through Y and continued until it meets the horizontal line through C2 at G. Draw a straight line through B from G, until it cuts the circular arc at J. A line from J to C_2 will intersect the springing line at C3, and with this point as centre and C3J as radius the arc JB may be drawn.

The other centres on the left-hand side may be found by measuring OC5 equal to OC3, etc.

The bed joints of the voussoirs should be found on the centre dotted line, as before.

Ogee Arch

Fig. 146 illustrates a method for describing the ogee arch. The centre dotted lines forming the upper part of the arch are tangent at the bottom of the string mould YZ.

With C1 as centre, C1A as radius, describe the semicircle A*d*B. Draw a line from A to D, intersecting the semicircle at E, and from C1 draw a line through E until it meets the horizontal line at C2.

[1] Note, if seven centres were required, these lines must be divided into four parts, and if nine centres were required, five parts, and so on.

With C2 as centre, C2E as radius, complete the ogee shown

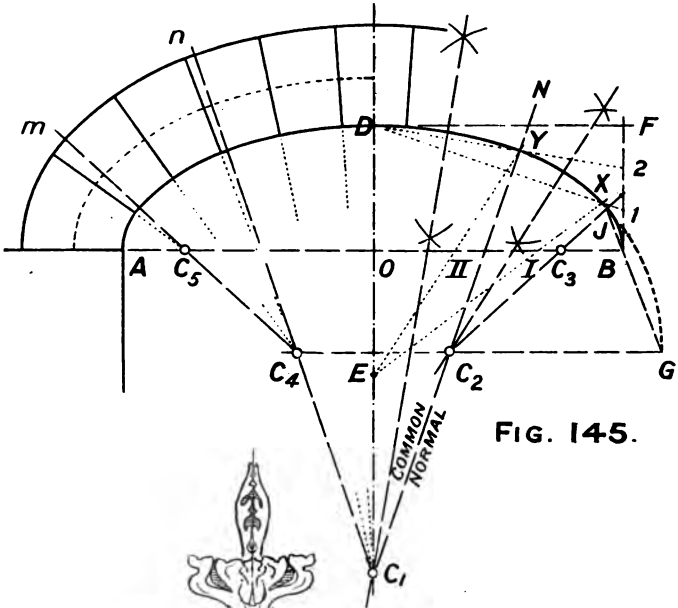


FIG. 145.

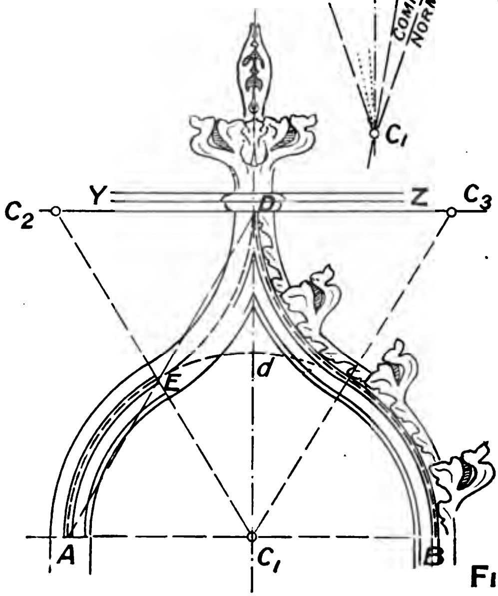


FIG. 146.

in dotted lines. C3 is found by measurement, and the other lines forming the moulding are described from these centres.

There are many methods for describing the ogee arch, but the above may be adapted to suit almost any example.

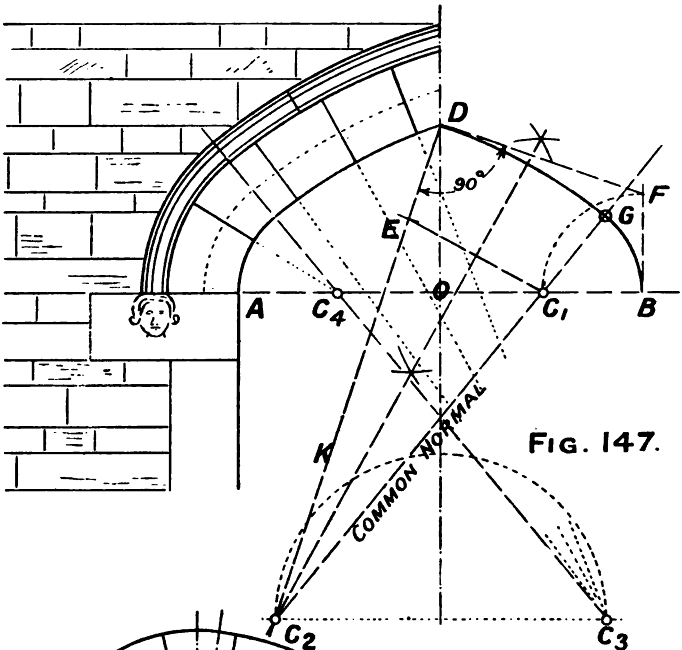


FIG. 147.

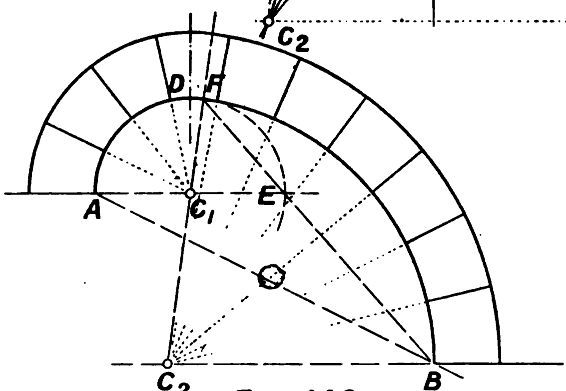


FIG. 148.

Fig. 147 illustrates a four-centred or Tudor arch.

AB is the span, OD the rise. From B erect the

perpendicular BF, and make BF equal to two-thirds the rise OD. (NOTE.—BF may be any distance less than OD; but it will be found that by making BF two-thirds OD a very good curve is described.) Join DF by a straight line and draw DK at right angles to it; make DE and C1B equal to BF, join E C1 by a straight line and bisect. The bisection line cuts DK at C2. Draw a line C2, C1, which is the common normal. With C1 as centre and C1B as radius, draw the arc BG; with C2 as centre and C2G as radius draw the arc GD, which completes one side of the soffit. C2 and C4 can be found by measurement.

The arcs forming the extrados and label are described from the same centres. The voussoirs should be stepped off on the dotted line as before described.

Fig. 148 illustrates a **Rampant arch**, which sometimes occurs on a staircase. AB is the falling line and springing points, the crown of the soffit being at D.

With C1 as centre and C1A as radius, describe the semicircle ADE. Draw a line from B through E, cutting the semicircle at F. From F draw a line through C1 intersecting the lower horizontal line at C2. With C2 as centre, C2F as radius, complete the soffit.

Another method for describing this arch by arcs of circles is explained in mouldings (see Fig. 85).

A more pleasing curve may be found by describing an ellipse through the points ADB (see Figs. 86 and 90).

THE SEMI-ELLIPSE ARCH

There are many methods for describing the ellipse, and it is not always possible, in full-size draughting, to use the same method. Figs. 149 to 153 show five useful methods.

Fig. 149 shows a method for finding a number of points in the curve, through which a freehand line may be drawn or a bender may be used.

AB is the span or **major axis**, OD the rise or **semi-minor axis**. Draw AE parallel to OD and of equal length. Draw ED parallel to AB, and equal in length to AO. Divide AO into a number of equal parts, as at I, II, III, and divide AE into the same number of equal parts, as 1, 2, 3. Make OG equal to OD, and from G draw lines through the points I, II, etc., until they intersect lines 1D, 2D, etc. The intersections of these two series of lines are points in the curve. The right-hand side may be drawn in the same manner.

Fig. 150 shows another method for describing the semi-ellipse by finding points in the curve.

AB is the major axis and OD the semi-minor axis. From O with radius OA describe a semicircle AEB, and from the same point with radius OD describe the semicircle FDG. From O draw the radials 1O, 2O, 3O, etc., and where they intersect the outer semicircle draw perpendiculars.

Draw horizontals from the points I, II, III, etc., in the smaller circle, which meet the perpendiculars at *m*, *n*, *p*, etc., which are points in the curve.

In both examples it will be found necessary to take a large number of points to ensure the draughting of a fair curve.

Fig. 151 shows a mechanical method for describing the semi-ellipse, and, provided the material used was quite reliable, would give a perfect curve.

AB is the span, OD the rise. From D, and with half the span AO, mark off F F1 on the springing line, that is FD and F1D are equal to AO. F and F1 are known as the FOCI of the ellipse.

Fasten a piece of string or twine at F and F1 in such a manner that when drawn tight it will just touch D. The string would thus be the exact length of the major axis.

Place a pencil at the angle of the string, and by moving the pencil and keeping the string taut a fair curve should result. Owing to the tendency of the string to stretch it is a somewhat difficult operation to obtain a perfect curve.

Fig. 152 shows another mechanical method for describing the ellipse.

AB is the span, OD the rise. A square or two fillets of wood are fixed to the board with their edges coinciding with the springing and centre lines. M and N are pins which slide along the edges of the square. (NOTE.—When fixing the square to the board, half the thickness of the pins should be allowed between the edges of the square and the springing and centre lines.)

The peg M is fixed in the sliding rod, and P is a hole in the rod to receive the pencil. PM is made equal to half the span—*e.g.* OA—and PN is made equal to OD. The pencil P will describe the curve whilst the pegs MN are sliding along the edges of the square.

*mn*P1 shows the sliding rod in another position.

Fig. 153 shows another method for describing the ellipse,

Two fillets may be used instead of the cross tee, in a similar manner to that described in the foregoing example.

The cross tee *lfg* is fixed so that the centre lines of the

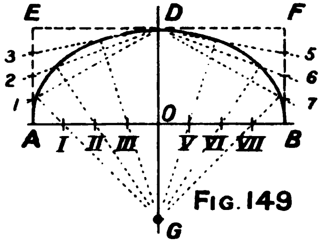


FIG. 149

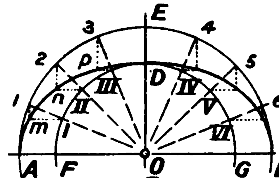


FIG. 150.

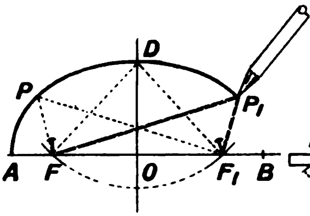


FIG. 151.

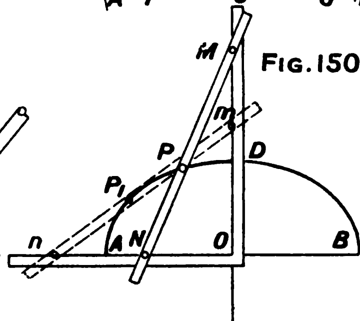


FIG. 152.

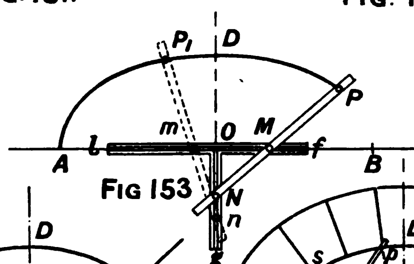


FIG 153

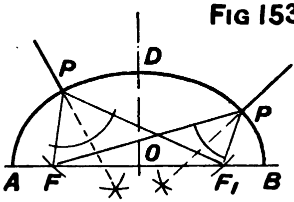


FIG. 154

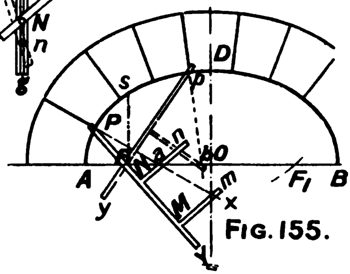


FIG. 155.

grooves are immediately over the major and minor axes. The trammel rod is placed over the centre line, P the pencil coinciding with the crown of the arch at D; the peg M

is placed and fixed to the rod, making PM equal DO or the semi-minor axis.

The trammel rod is then placed above the springing line with P the pencil point on A, and the peg N is fixed to the rod at O, making PN equal AO or the semi-major axis. MN then equals the difference of the semi-major and the semi-minor axes, and whilst M slides along the horizontal groove, N slides down and up the vertical groove, the pencil P describing the semi-ellipse. P1*mn* in dotted lines shows the trammel rod in another position.

To find the bed joints, which should be normal to the curve. Set off the foci F and F1 (Fig. 154) as described. Prick over the arch and place the joints in convenient positions. Draw lines from F to P and P to F1, P being a position at which a normal is required; bisect the angle F P F1, and the bisection line will be the required normal to the curve. Any number of joints may be found in a similar manner.

Fig. 155 shows a mechanical method for finding normals.

PY is a rod having two arms N*n* and M*m* fixed perfectly square to it. Find the foci F and F1 as before described, and from F erect a perpendicular until it touches the ellipse at S. PN on the rod should be made equal to this line SF, the semi-latus rectum. PM should be made equal to AO, the semi-major axis. Place P on the rod at the point on the curve where the normal is required, and the edge of the rod should pass through the point F on the springing line; the cross arm N*n* will cross the springing line at *a* and the normal may be drawn through P*a*. It will be noted that the arm M*m* intersects the centre line or minor axis at the same point as the normal.

It is not essential to have the arm M*m* on this tool, the arm N*n* giving us all the points for the normals on the springing line, except when a normal is required at S, when edge of the arm N*n* coincides with the springing line.

In this case the normal may be found as described in the previous example, or the second arm M*m* may be used, and will cross the centre line at another point in the normal.

In small drawings, this method may be adapted by using tracing paper, and pricking the required points *ab* through the tracing paper on to the springing line.

The extrados of an ellipse arch is often described by means of an ellipse, but this is incorrect. The extrados should be parallel to the intrados, and ellipses cannot be drawn parallel

to each other. The face of the arch should be measured on the normals, and a bender used to obtain the curved line.

If a template of the ellipse is made in wood, the extrados may be drawn by sliding a gauge along the edge of the template.

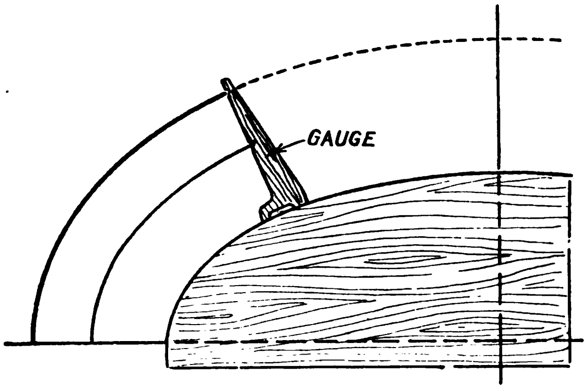


Fig. 156.

whilst a pencil at the other end of the gauge would describe the curve [1] (see Fig. 156).

In setting out ellipse arches great care should be exercised that the different crafts—*e.g.* joiners, bricklayers, and masons—have exact information as to which line, the soffit of the arch or the joiner's frame, is to be the ellipse.

[1] This is not accurate, but if the gauge is carefully used a fairly reliable curve will result.

CHAPTER IV

CONSTRUCTION AND CONSTRUCTIONAL DETAILS

Foundations.—Foundations are necessary to every building, as a base upon which to erect the superstructure. They are designed to prevent inequality of settlement, and are usually arranged to spread the weight of the structure over a larger area. They vary with the size and type of building, and the kind of earth upon which they are built.

Careful calculations have at times to be made, to decide the depth and spread of the foundations, and trial holes are dug to assist the designer in forming a judgment as to the difficulties he is likely to encounter.

At this stage it is only necessary for the student to understand general rules.

Trenches must be dug in the soil, into which the concrete, which usually forms the base, is placed. It is often necessary to support the sides of the trenches during the operation of digging, and the subsequent operation of building the footings.

The supports in small trenches are of timber, and the type of support depends upon the nature of the soil.

In firm ground **poling boards** and **struts** are used. The poling boards being usually about 3′ 0″ × 9″ × 1½″, and the struts the butt ends of poles or 4″ × 4″ square timbers. The struts should not be placed less than 6 feet apart, as a smaller distance would inconvenience the excavators (see Fig. 157).

When it is necessary to place poling boards at more frequent intervals, they are further supported by a **waling timber** of 6″ × 4″, 7″ × 3″, or some other convenient scantling (see Fig. 158).

Poling boards may be placed close together if desirable; but where earth is unreliable, boards are laid horizontally in the trench, the earth is taken out to a depth of 9 inches, and a

9″ × 1½″ board is laid each side of the trench and strutted apart; another 9 inches is taken out and boards are again

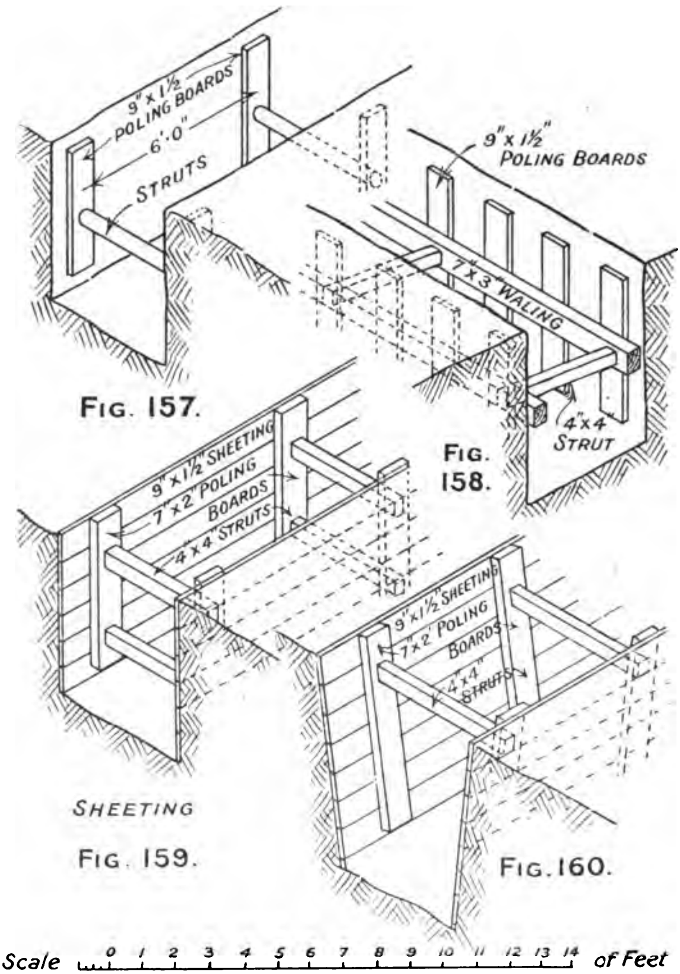


FIG. 157.

FIG. 158.

FIG. 159.

FIG. 160.

placed underneath the former, and temporarily strutted. This operation is repeated until there are sufficient boards in position to use a poling board on each side, which are strutted

apart. This type of timbering is known as **sheeting** (see Fig. 159).

In very treacherous soils the sides of the trench may be tapered towards the bottom; this enables the struts to be made more secure (see Fig. 160).

In all cases care should be exercised when marking out the ground to be excavated that there will be sufficient room at the bottom of the trench to receive the specified amount of concrete.

Large excavations and deep trenches need special treatment, and the reader is referred to the many excellent books that specialize on timbering for excavations, which becomes a branch of carpentry.

Concrete is generally used as the base of the wall, and is placed in the bottom of the trench, the wall with stepped footings being built on top.

In districts where stone is plentiful, slabs of stone of from four to eight inches thick are often used.

The courses may be of varying height, but all the stones composing each course should be of the same height, and should pass right through from front to back in one piece.

Each course projects from 3 to 6 inches beyond the course above, on each side of the wall, and the lowest course is usually about twice the width of the wall above (see Fig. 162).

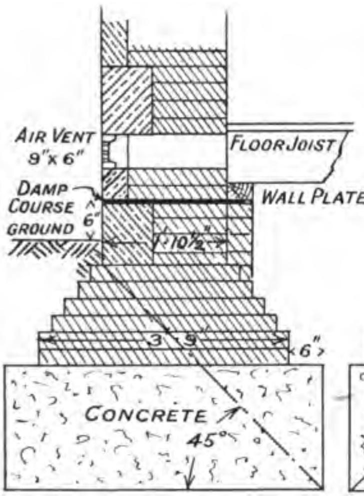
When bricks are used as footings, it is usual to make the lowest course twice the thickness of the wall, and to step back 2¼ inches on each side until the correct thickness of wall is obtained (see Fig. 161). The concrete projects from 4 to 6 inches beyond the lowest course of footings (see Figs. 161, 162).

It is found by experience that concrete usually fractures at about 45° to the base of the wall, and a safe margin would be allowed if the depth of the concrete is decided by drawing a line at 45° from the bottom of the wall to the vertical edge of the concrete (see Figs. 161, 162).

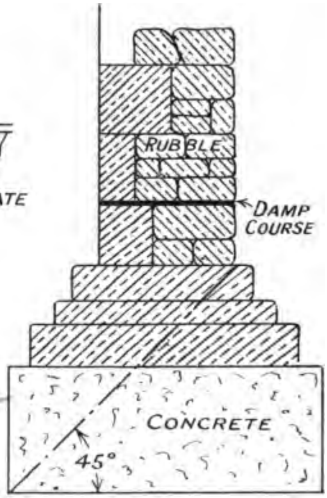
In soft and boggy soils, pile foundations, either of timber or ferro-concrete are used, the piles being driven until they reach firm ground, the tops of the piles being embedded in a base of concrete.

Grillage foundations are sometimes used. Rolled steel joists embedded in concrete are used to spread the weight over

a larger area and to prevent fracture of the concrete (see Fig. 163).



STONE FACE
BRICK BACKING.
FIG. 161.



ASHLAR FACE
RUBBLE BACKING.
FIG. 162.

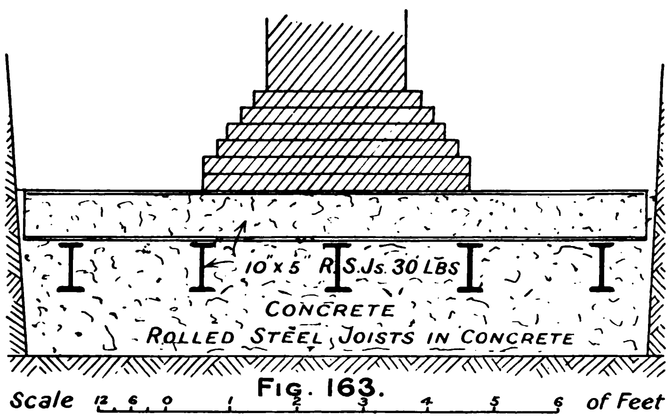


FIG. 163.

Reinforced concrete, in the form of rafts, is also used where heavy buildings are erected on unreliable ground.

Damp-Proof Courses

To prevent damp rising up the wall from the surrounding earth, a layer of some impervious material is necessary. This is known as a **damp-proof course,** and a number of materials are used for the purpose.

Two layers of good slates set in Portland cement, and laid so that the joints in each course are not immediately over one another, make a good damp course. Any irregular settlement of the building, however, is likely to break the slates and thus destroy their effectiveness.

Asphalte.—A layer of asphalte is often spread over the wall when hot and in a mastic state, as a damp course; but it has the objection in a tendency to squeeze out, due to pressure of the superincumbent building.

There are many good bituminous asphalte sheetings manufactured specially for this purpose. They are made up in standard widths and should have a good lap at the joints. Many of these sheetings make very good damp courses. Sheet lead makes a good damp course ; but besides being much more expensive, there is a lack of adhesion between the mortar and the lead. In the case of stone walls with worked beds this objection is not so great, and if the lead is of suitable weight, and properly placed in position, makes a very good damp course.

Vitreous stoneware slabs of from two to three inches thick, and having horizontal perforations, and perforated or keyed joints, make good damp courses. There are several good varieties on the market.

Damp courses must be laid six inches above the ground to comply with the bye laws (see Fig. 161).

Where floor-levels are below the ground, some method must be adopted to prevent moisture percolating through the wall.

Vertical Damp Courses and Dry Areas are designed to avoid this trouble.

Damp courses, either of slate, asphalte, or sheeting, are placed on the face of the wall between the wall and the earth (see Fig. 164).

Vertical damp courses are also incorporated with the wall, a space being left between the face and the backing, which is afterwards filled up with asphalte or other impervious material. Bitumen sheeting is sometimes used (Fig. 165).

Dry Areas, when properly built, form a very effective

method for preventing moisture percolating from the outside soil into the building.

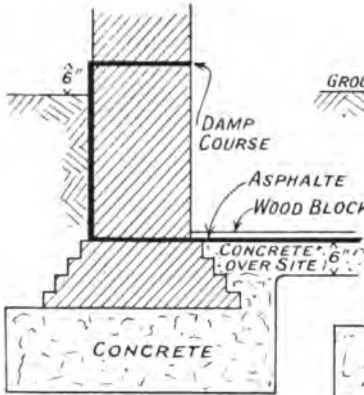


FIG. 164.

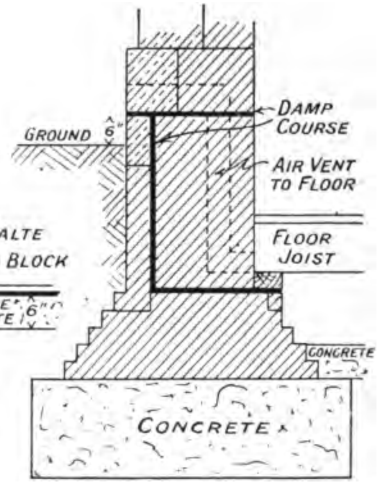


FIG. 165.

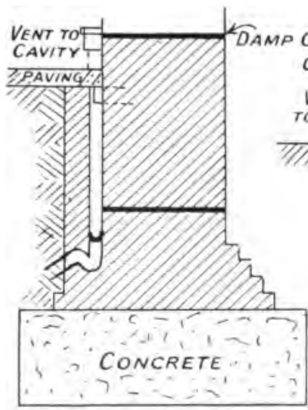


FIG. 166.

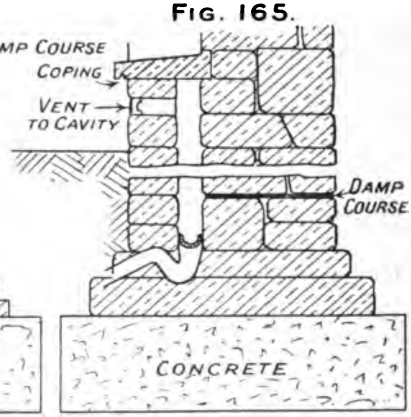


FIG. 167.

Scale 12 6 0 1 2 3 4 5 6 of Feet

A dwarf independent wall is built on the face of the main wall, leaving a cavity which should be properly drained and

ventilated. This dwarf wall should be tied or bonded to the main wall by means of galvanized iron ties or bonding bricks (see description of hollow walls), and may be coped as in Fig. 167, or covered with the paving as shown at Fig. 166.

Dry areas may also be open, formed by a small embankment or revetment wall, to support the outside earth. The area should in such case be large enough to permit the entry of a man for cleaning purposes. The area should be paved and provided with a gulley and drain.

It is necessary, to prevent dry rot in timber floors, that a free current of air should pass beneath the floor and between the joists. Air bricks, either of terra cotta or other burnt clay, or of cast iron $9'' \times 3''$ to $14'' \times 6''$, are used for this purpose. A hole of this dimension is left in the wall and faced with the air-brick described (see Figs. 161, 165).

The whole of the site of any building should have the top spit of mould removed and the earth levelled, and a layer of Portland cement concrete six inches thick should be laid over the whole surface. This is usually provided for by the local bye-laws of the district.

Stone Walls

All walls need careful bonding to ensure stability, and to equally distribute the pressures placed upon them.

Bricks being of uniform size and standard dimensions, precise and standardized systems have been evolved, to ensure this uniformity of bond throughout the wall.

Stones being of unequal size and shape, need special care and arrangement to obtain a perfect bond throughout the mass, and varies with almost every building erected.

Bond consists of arranging the stones in such a manner that each stone distributes the pressure it receives to the largest number of stones below.

All vertical joints are a source of weakness in a wall, and the stones both above and below should cover or overlap this joint, and so interlace or intertie the whole of the stones composing the wall. This is known as "breaking joint," and when two or more vertical joints are above one another, is known as a straight joint.

Straight joints should as far as possible be avoided, but in many of the rubble walls, are necessary, to allow the smaller stones to make up the height of the larger ones. Even in

rubble walls, no more than four joints should be arranged in a straight line, and then as few as possible.

Bonding should not only take place upon the length of the wall, but also transversely across the thickness of the wall. A wall may appear perfectly bonded upon the face, yet imperfectly bonded internally.

No hard-and-fast rule can be given as to the amount of overlap or bond. The reader should exercise his judgment, in arranging the stones in the best possible manner to comply with the foregoing conditions.

Thickness of Walls.—Each district has its own bye-laws, which in general agree with the schedule of the London Building Act for the thickness of walls. This schedule gives the thickness required for all classes and types of buildings; for walls constructed of "bricks, stone, or other similar substances"; and further states that "The thickness of every wall not being built of bricks or stone, or other hard and incombustible substances laid in horizontal beds or courses, shall be one-third greater than the thickness prescribed in Parts I. and II. of this schedule."

Rubble walls, unless coursed, must therefore be built one-third thicker than walls of brick or regular coursed stone.

Rubble walls of any description are often looked upon by the banker mason as quite outside the craft of masonry, and indeed quite a distinct trade is set up in various parts of the country, of men who work and build these stones for rubble walls.

Masons who take an interest in their work must recognize that all building in stonework is part of their craft, no matter how rough the work may be, and that this specialization of the different sections is entirely due to economic causes.

Rubble Walls differ in construction and appearance in the different districts according to the nature of the stone found in that district, and one should expect to find rubble walls in the north of England, where there is a large amount of stone of a laminated nature, different to the rubble walls in the limestone districts, where lamination is not so marked.

This difference in the physical structure of stone found in the various districts has not only played its part in rubble walls, it has controlled the architectural history of the nations to an extent not always accepted by the historians.

Flint is used in districts where chalk abounds for building walls. The flints are found embedded in the chalk, and large

quantities are found under the chalk. Large pieces are sometimes split, chipped square and built in regular courses; or smaller flints are split, the split surface forming the face; or thirdly, the flint pebble is used in one piece.

Bonders or lacing courses of larger stones or tiles should be used to give longitudinal and transverse strength, and the angles at the ends of walls, doors, windows, etc., should be built in wrought stone or brickwork.

Figs. 168, 169 show an elevation and section of a flint

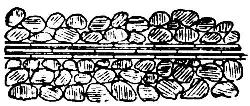


FIG. 168.

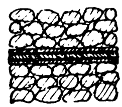


FIG. 169.

rubble wall, with three courses of tiles laid right through the wall to bond the work together.

This tile course is known as a **lacing course**, and sometimes flat stones, wrought stone, or bricks are used in the place of tiles.

Fig. 170 illustrates what is known as **Flint Tracery.** Wrought stone forms the tracery, and the flint is built in the panels.

The flint in the example has been split and roughly squared. The flints are sometimes used whole with rough joints, as before described.

Fig. 171 shows a form of **diaper work.**

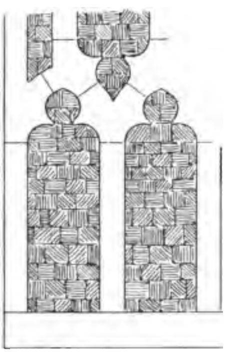


FIG. 170.

FIG. 171.

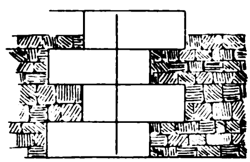


FIG. 172.

Wrought stone is placed chequerwise and the flints are built in between, the worked stone forming a series of bonders with the wall.

Other forms of diaper work consist of carved stone blocks laid alternately with plain stone blocks, or of carved blocks built in the wall in the form of various patterns.

The stones are of varying shapes, and may be square, lozenge, hexagonal, etc.

Fig. 172 shows a flint wall with a wrought stone quoin.

Fig. 173 is a photograph of flint facing with split or polled face and having chalk bonders.

Random Rubble.—In many districts where stone abounds fences between fields are built of rough stone, practically quarry refuse, no mortar being used. This is known as dry rubble ; the top stones are bedded in mud or earth to keep some of the rain

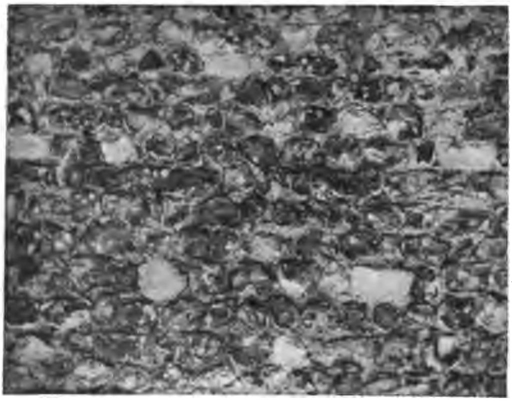


Fig. 173.

from the interior of the wall, and to assist in binding the stones together.

When set in mortar, a little more care is exercised in building, the waller knocking off the rough inequalities to approximately fit adjacent stones.

Fig. 174 is an elevation of a rough, common, or random rubble wall, built of laminated stones.

Fig. 175 is a section on the line AA ; note the through bonder.

Fig. 176 is an elevation of a random rubble wall built of stone that is not laminated.

Fig. 183 is a photograph of a random rubble built of various stones.

Random Rubble built to Courses consists of rough stone set in mortar as before described, but roughly levelled up from every twelve to eighteen inches in the form of courses. At each

course the wall is flushed up with mortar, which is pressed into

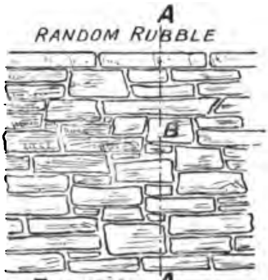
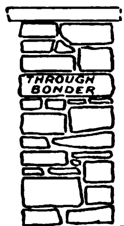


FIG. 174.



SECTION AA

FIG. 175.

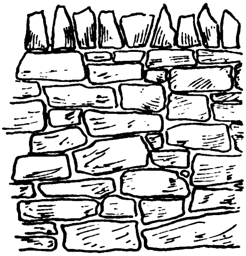


FIG. 176.

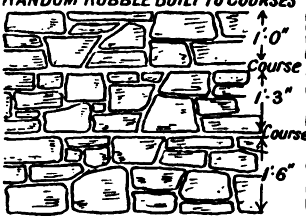
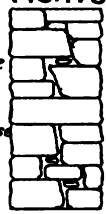


FIG. 177.



SECTION BB.

FIG. 178.

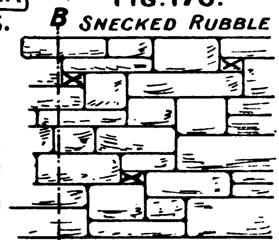


FIG. 179.

⊠ SNECKS.

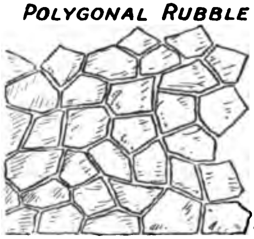


FIG. 180.

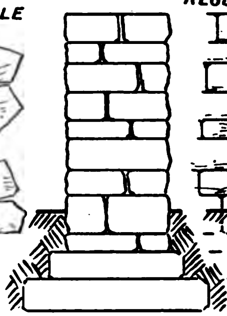


FIG. 181.

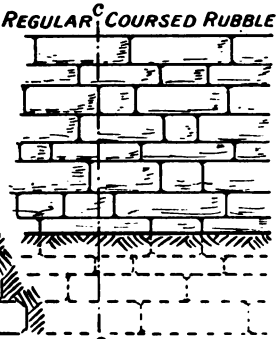


FIG. 182.

Scale 12 9 6 3 0 1 2 3 4 5 6 7 8 9 of Feet

the crevices of the interior of the wall. This flushing up makes a better and stronger wall.

Fig. 177 is an elevation of a wall of this type. Fig. 184 is a photograph of the same type of wall.

FIG. 183.

Squared or **Snecked Rubble** consists of stones of varying thickness, the beds and joints being roughly squared. The face

FIG. 184.

may be roughly pitched or hammer dressed. It is sometimes known as uncoursed or irregularly coursed rubble.

Fig. 179 is an elevation; Fig. 178 a section through BB;

Fig. 185 is a photograph of a snecked rubble wall built in marble.

Fig. 185.

Squared Rubble built to Courses.—Snecked rubble is levelled up into courses in the same manner as random rubble,

Fig. 186.

and each course is carefully flushed up with mortar as before described.

Regular Coursed Rubble is shown in Fig. 182, Fig. 181

being a section on the line CC. The stones are selected mostly at the quarry, and sorted into thicknesses varying from three to nine inches in bed.

Fig. 186 is a photograph of a regular coursed rubble wall.

Compact and non-laminated stone often means that a considerable amount of labour must be placed on the beds, to correctly thickness the courses. It must be understood that in all rubble work the labour put on the stones is of the roughest description. Arrises, corners, angles are not studied; the principal tools employed being scabbling hammers, pitching tools, and wallers' hammers.

Polygonal Rubble, sometimes known as **Kent Rag Rubble,**

FIG. 187.

is familiar to the south-eastern district. The face of the stone is polygonal in shape, and the joints are pitched to roughly fit adjacent stones. Fig. 180 is an elevation; Fig. 187 a photograph of a polygonal rubble wall.

Block in Course is principally used for engineering work, such as sea, harbour, and embankment walls, and consists of large blocks of hard stone with worked beds and joints, and hammer-dressed or pitched faces. Block in course is now largely superseded by concrete in one of its forms.

Composite Walls.—It is the practice to use **ashlar,** *e.g.* wrought stone, on the face of a wall, and building the back of the wall in brick or rubble. In either case the backing should be levelled up to each course of the face work, and it is pre-

ferable to build the back in cement mortar to avoid unequal settlement, owing to the thicker and greater number of beds in the backing material.

Stone when used with brick backing should be made in three, six, nine inch or some multiple of a brick in height, with this object in view.

Figs. 161 and 162 illustrate two kinds of composite walls.

Hollow or Cavity Walls.—In many districts driving rains are found to pass right through the external walls, causing excessive damp in the interior of the building. Walls with a vertical damp course are built with the object of preventing damp and moisture passing to the interior of the building; but probably the most successful method for preventing moisture penetrating to the interior, is the hollow or cavity wall. It consists of a face wall of brick or stone from 4½ to 9 inches in thickness and a main wall that supports the floors and roof. The two walls being separated by a cavity two inches or more in width.

The face wall must be fastened to the main wall by means of iron ties or bonding bricks, which should be placed apart about three feet horizontally, and eighteen inches vertically.

If iron ties are used they should be galvanized or treated to prevent oxidization, and should be twisted or kinked so as to prevent the water passing on to the main wall.

The bottom of the cavity should be provided with a channelled gutter and drained. The cavity should be ventilated by means of air bricks, and all openings should be made secure against the entry of rats.

Special means must be taken to prevent moisture coming into contact with woodwork in door and window openings, and a lead gutter is formed above each opening, the lead projecting three or four inches beyond the framework so that any moisture would drip clear of the wood.

Water must be prevented from percolating through from above, and a damp-proof course should be placed immediately beneath the coping, the top few courses of the work being built in cement mortar.

Fig. 188 is an isometric sketch of a hollow wall showing a bonding brick in position. Fig. 189 shows a section through a cavity wall and window opening, with lead gutter above the concrete lintel. Fig. 190 is a horizontal section through a jamb of a window opening. Fig. 191 is a sketch of an iron tie.

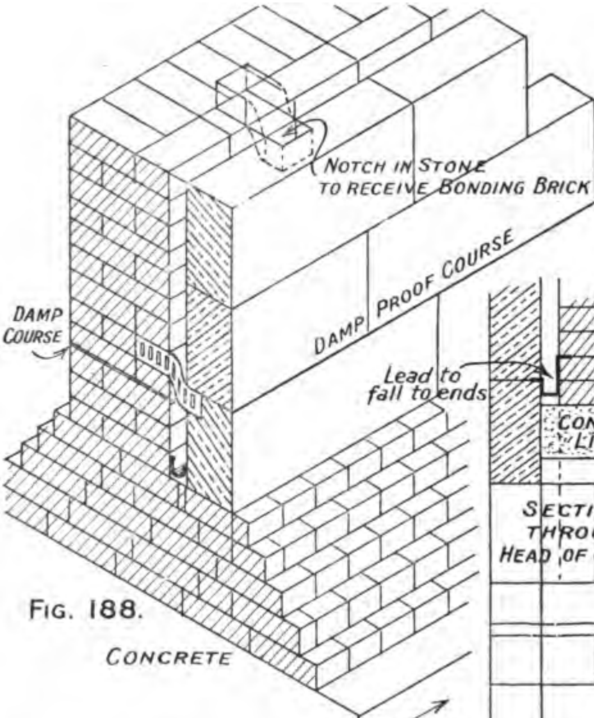


FIG. 188.

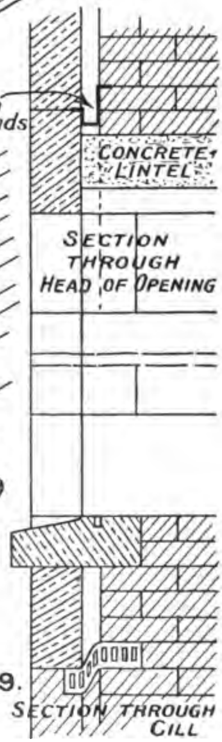
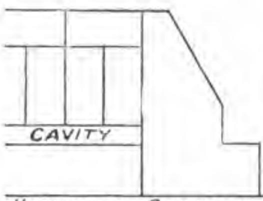


FIG. 189.



HORIZONTAL SECTION
THROUGH WINDOW OPENING
FIG. 190.

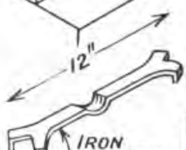


FIG. 191.

Scale 12 6 0 1 2 3 of Feet

Bonders.—All walls require bonders ; that is, stones passing through the thickness of the wall. When passing through from front to back, they are known as **through stones,** and

stones passing partly through the wall are known as **bonders** or **three-quarter bonders.**

Through stones have the advantage of a better tie, or bond, but have the disadvantage of allowing moisture to pass into the interior of the wall by capillary attraction, and three-quarter bonders, are for this reason, sometimes preferred.

A piece of slate, tile, or other impervious material placed on the interior side of a through bonder is often used to prevent damp passing through the wall.

Ashlar is generally accepted as carefully wrought stone, faced in accordance to the physical structure of the material, or the discrimination of the designer. The courses are not necessarily of equal depth.

The word "ashlar" covers a wide understanding of face-work, and we often further distinguish by adding a prefix as **plain, rebated, rusticated,** etc.

Various devices are adopted to elaborate the face of stone-work, not always with happy result; but in many instances they break up what would otherwise be monotonous flat surfaces, or produce shadow effects both pleasing and restful to the eye.

Boasted or **droved** (Fig. 192).—The face is worked with a boaster, and the chisel marks are usually regular and at the

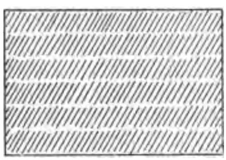


FIG. 192.—BOASTED.

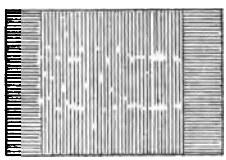


FIG. 193.—TOOLED.

same angle on the one stone, whilst the adjacent stone may have the chisel marks at a different angle, and either closer or further apart, in accordance with the individuality of the mason employed on each stone.

The chisel marks are sometimes made of precisely one angle throughout, and at the same distance apart, at the caprice of the designer.

Tooled or **stroked** (Fig. 193) consists of regular chisel marks extending right across the stone. The stone is sometimes carefully surfaced before the tooling is done, and in such case considerable care is exercised in getting what is really a

system of small flutes right across the stone. Tooling is, however, done to rough self-faced stones used for paving, and this is only a rough form of surfacing to assist foot grip.

Punched or **broached** (Fig. 194) shows a series of ridges right across the stone and parallel to each other, produced by

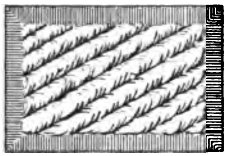


FIG. 194.—BROACHED, TOOLED MARGIN.

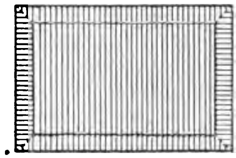


FIG. 195.—FURROWED.

either a punch or a point, according to the fineness of the work and the hardness of the stone.

A surface covered with a series of cavities caused by the punch being driven into the stone whilst in a nearly vertical position is also known as **punched** (see Fig. 196). The cavities are near together or further apart according to the toughness of the stone and the effect required by the architect. When

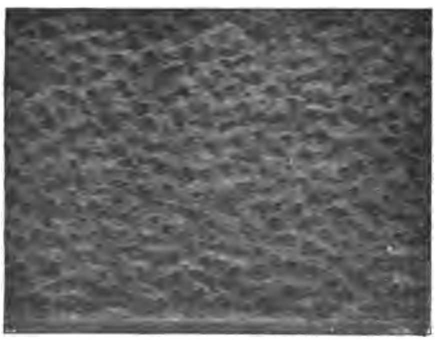


FIG. 196.

the cavities are close together the work is known as **picked** or **pecked,** and very fine pecking, usually done by a sharp mallet-headed point, is known as **sparrow pecked.**

Furrowed or **fluted** (Fig. 195) consists of a series of small flutes worked right across the face of the stone. It must not be confused with tooled work. The process is a very expensive

one, as the stone is first brought to a plane face, and the lines denoting the arrises of the flutes are scribed on the surface, and the flutes worked with round-nosed tools, gouges, and boasters, and finally rubbed or combed smooth.

Reticulated (Fig. 197) consists of a series of sinkings or pockets in a smooth surface, the margins between the sinkings being of fairly regular width, varying from three-eighths of an inch upwards according to the scale of the work.

The bottom of the pockets or reticules are worked in a variety of ways, *i.e.* rubbed, pecked, etc.

Vermiculated (Fig. 198).—The sinkings in this facework

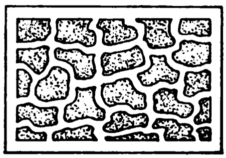


FIG. 197.—RETICULATED.

FIG. 198.—VERMICULATED.

are very irregular, to give the appearance of a worm-eaten surface.

Rusticated is a somewhat general term, and covers a number of various finishings. Rusticated work is understood as projecting courses of stonework, the individual and projecting stones being known as **rustics** (see Fig. 199).

Rebated and Moulded Joints (Fig. 200) are all known as rusticated work. Projecting stones in columns and piers, whether worked or unworked, are known as rustics, and the work as rusticated. The reader should therefore be careful in his description and definition of rusticated, which covers a variety of finishings for projecting blocks.

Openings in Walls.—Door and window openings are necessary for ingress and egress, light and air. The heads of the openings, either in the form of lintels or arches, have been explained in the chapter on drawing and setting out.

Relieving arches are often used over lintels to discharge the weight from above to the abutments, thus relieving the lintel of the load. They are also used on the interior of the wall for the same purpose, in which case they are usually of rough stone or brick.

Fig. 201 illustrates a relieving arch on the face of the wall.

Fig. 202 illustrates elevation of relieving arch on the interior of a wall. Fig. 203 is a section through the wall.

RUSTICATED MASONRY.

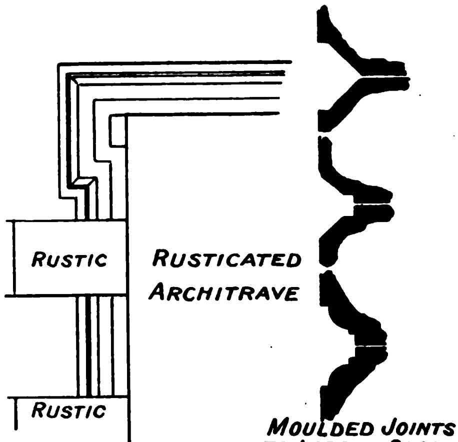


FIG. 199.

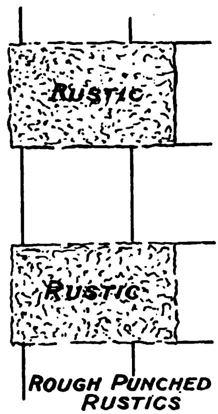


FIG. 199.

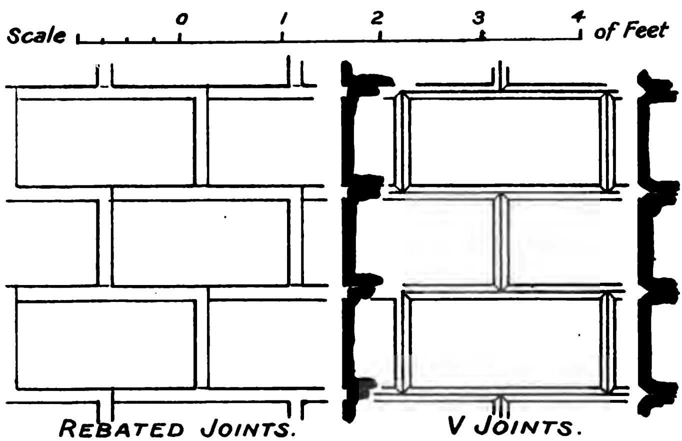
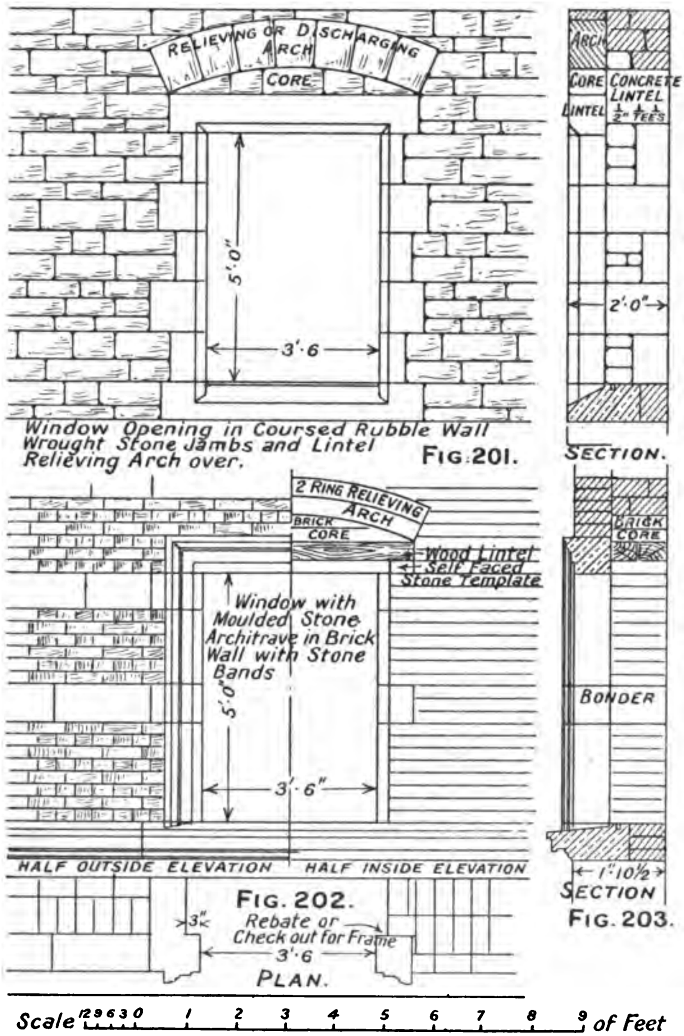


FIG. 200.

The cills of all window openings should be weathered, *e.g.* worked with a sloping top to allow the rain to run

off quickly, and they should be provided with a level seating



at the ends, to support the jambs. A level seating is also required to seat the mullion. These level seatings are

known as **stools** or **stooling** and are illustrated in Figs. 204 to 206.

Fig. 204 illustrates a stooling of a common type.

The seating (Fig. 205) is allowed to project outside the face of the wall, forming a stop to prevent the water running down the end of the cill on to the wall. This does not leave a parallel edge on the front of the cill, and Fig. 206 illustrates an alternative.

When a wood cill is to be fixed on top of a stone cill, an iron bar is let into the wood and stone to prevent water from soaking between.

The **water bar** or **iron tongue** is from $1'' \times \frac{1}{8}''$ to $1\frac{1}{2}'' \times \frac{3}{8}''$, and should be galvanized and run the whole length of the cill in one piece. The wood cill should be bedded on to the stone cill with red and white lead.

Window cills should be bedded solid under the jambs and mullions to support the weight placed upon them, but they

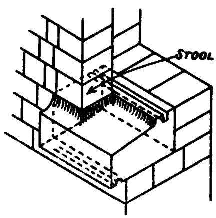


FIG. 204.

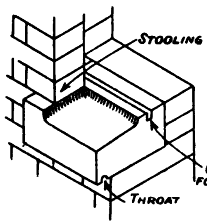


FIG. 205.

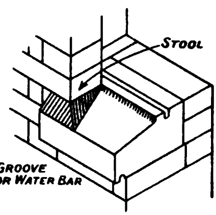


FIG. 206.

should be left hollow immediately under the opening and the space pointed up after erection. This often avoids the fracture of the cill, due to the settlement of the building.

Rebates and check-outs are usually left for door and window frames, which are fixed into position after the masonry is built.

Mullions are vertical bars dividing the window opening into **lights** (Fig. 207).

Transoms are horizontal bars dividing the window into **lights**. Transoms should be weathered on their upper surface in the same manner as cills, and stools should be left for jambs and mullions.

Leaded lights are usually fixed into grooves cut into the jambs and head. The lead light is bent so as to pass through the sight opening, and then pressed out straight until it passes into the provided grooves, which are pointed up with Portland cement mortar (see Fig. 208) or mastic.

Saddle Bars are fixed into the stonework to further support the leaded light and to prevent its sagging. They are usually

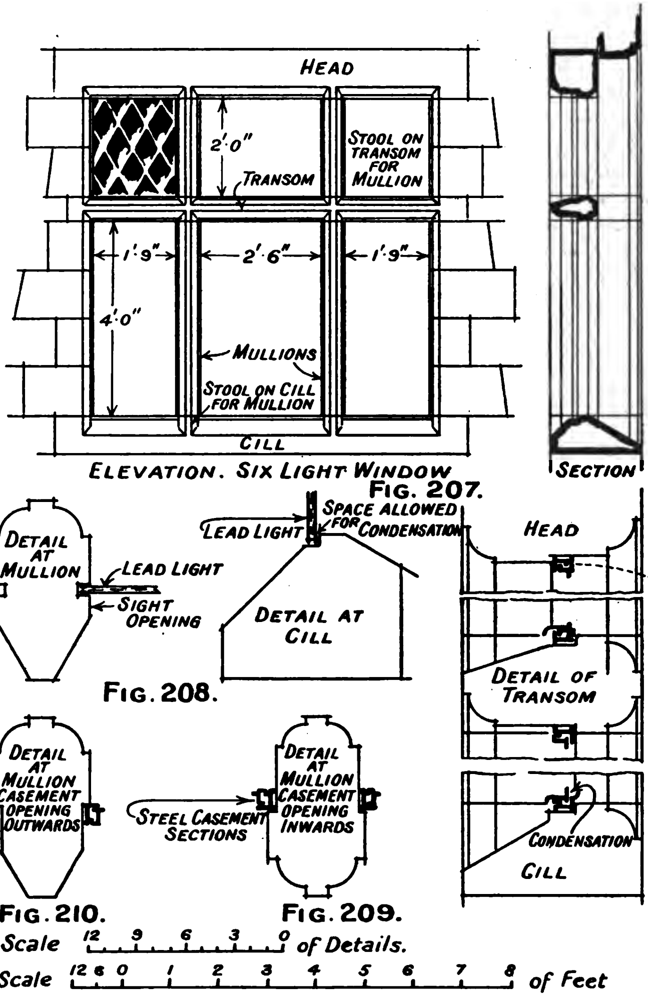


FIG. 207. FIG. 208. FIG. 210. FIG. 209.

of iron, three-eighths to three-quarter inch diameter, round or square; and the lead light is tied to these with copper wire soldered to the lead came of the lead light.

There are now several patents on the market to enable the glazier to make the lead light sufficiently rigid, and omit the saddle bars.

Owing to the more extensive use of metal window frames and casements, special rebates have to be provided in jambs, mullions, transoms, and cills, to receive the different maker's specialities.

Figs. 209, 210 illustrate suitable rebates for inward and outward opening casements respectively; but the mason should always be provided with a drawing showing the requirements of the frame-maker.

Bay Windows are windows that project from the face of the main wall, forming bays in the room (Figs. 211, 212).

Oriel Windows differ from bay windows in that they are corbelled out from the main wall above the lowest floor or floors. Figs. 213, 214 illustrate an oriel window, showing the corbel courses and tailing iron.

The tailing iron is built into the main wall at the abutments, where the jambs are built on top as a counterfort to the corbel courses, and prevents overturning.

Other iron and steel work is often introduced in complicated structures.

Stairs.—Stairs consist of an arrangement of rectangular blocks or steps, designed to admit of easy access from floor to floor. They should be in a well-lighted chamber known as a **staircase,** and convenient to the entrance door. They may be supported between two walls (see Fig. 215), in which case they should enter the wall $4\frac{1}{2}$ inches, or they may be fixed into the wall at one end only, and are known as **hanging steps** (see Figs. 216 to 218). These steps should be fixed into the wall at least 9 inches.

Hanging steps are chiefly supported by the wall, but they also receive some support from the step immediately below.

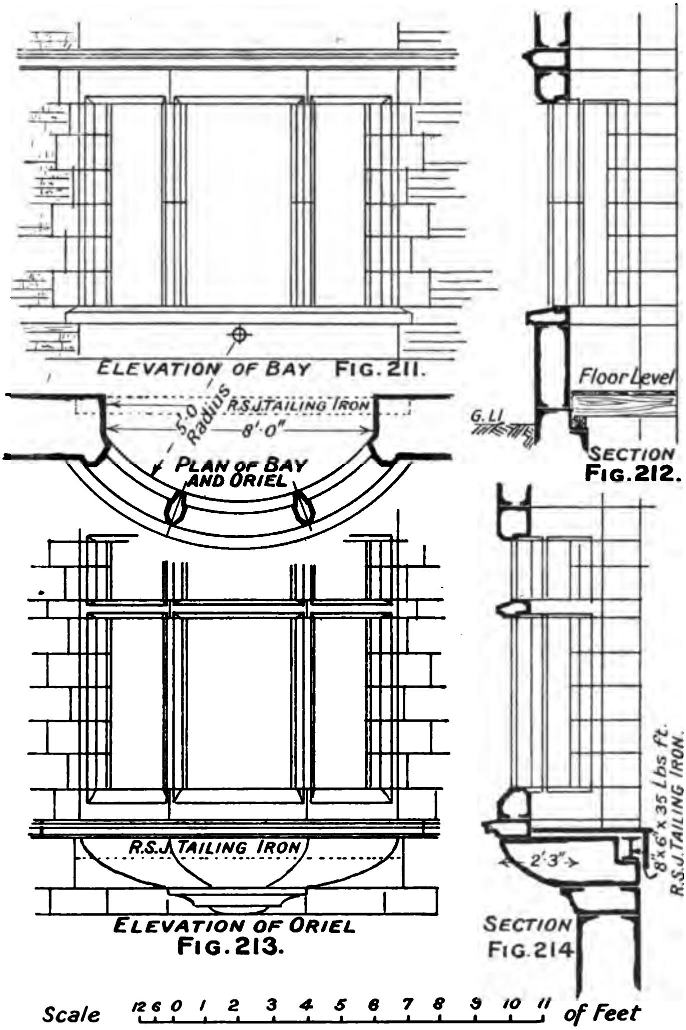
Where steps are very long they should receive additional support at their outer or free ends by means of a rolled steel joist; or they may be strengthened at intervals by means of cantilevers.

Flights of stairs should, wherever possible, be restricted to fourteen steps, and no two flights should proceed in the same direction, unless provided with a wide landing. Landings should never be narrower than the length of the steps.

Tread is understood as—

(*a*) The horizontal or upper surface of the step.

(*b*) The complete slab comprising the upper part of the step (see Figs. 221, 222).



(*c*) The horizontal distance from riser to riser (Fig. 226).

Rise.—The vertical distance from tread to tread, or in

reference to a flight, the vertical height from the floor to landing above. See Figs. 225 and 215.

Riser (*a*) is the vertical face of the step; (*b*) the vertical slab comprising the front of the step in a tread and riser stair (see Fig. 221).

Going, also known as tread, is—

(*a*) The horizontal distance between two risers (see Fig. 226).

(*b*) The horizontal distance between the riser at the bottom and the riser at the top of a flight (see Fig. 215).

Flight of stairs is a succession of steps without a landing.

Landings, Half space, extend right across the width of the stair (see Fig. 217).

Quarter space, occupies the angle of a staircase, the full width of the flight (see Fig. 216).

Flier is a straight step, one of a flight.

Winder, a triangular step, usually placed at the angle of a flight, and should always be arranged at the bottom (see Fig. 218).

A stair may consist of a succession of winders, and is known as a winding stair.

Kite winder, the centre of three winders in the angle (see Fig. 218).

Stairs should be so arranged to be of easy ascent, and there are various rules for proportioning the tread and rise. Treads should not be less than 9 inches wide.

Two methods for deciding the tread and rise are given; they vary with each other, and give different results for various proportions.

First method—

$$\textbf{Tread} \times \textbf{rise} = 66 \text{ ins.}$$
$$\text{or } 11 \times 6 = 66,$$

that is, an eleven-inch tread should have a six-inch rise.

If either the rise or the tread is known, it is only necessary to divide 66 by the known quantity to find the unknown.

Example.—The tread of a step is ten inches, therefore—

$$\frac{66}{10} = 6\tfrac{3}{5}'' = \text{rise}.$$

Second method—

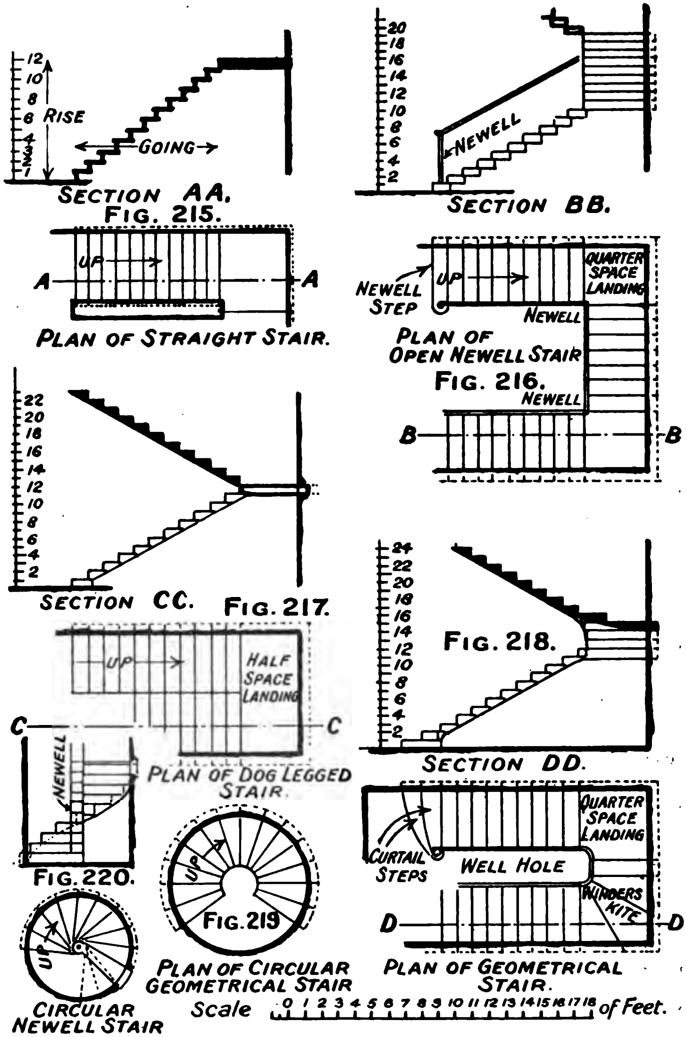
$$\textbf{Tread} + 2\textbf{rise} = 23 \text{ inches}$$
$$11 + (2 \times 6) = 23$$

If the rise is known, multiply it by 2 and subtract from 23; the remainder is the tread.

Example.—The rise of a step is seven inches—

$$23 - (7 \times 2) = 9 \text{ inches} = \text{tread}.$$

To find the rise when the tread is known subtract the tread from 23 and divide the remainder by 2.



Example.—The tread of a step is 10 inches—

$23-10=13,\ \frac{13}{2}=6\frac{1}{2}''=\text{rise}.$

Stairs are of different types. **Straight stair** (Fig. 215) has all the steps parallel and rising in the same direction.

Dog-legged Stair consists of a series of flights, rising in opposite directions. They are hanging steps, and the free ends of the steps in the upper flight are immediately over those in the lower flight, leaving **no well-hole** (see Fig. 217).

Winders may be arranged to take the place of the landing if desired.

Open Newell Stair consists of a series of straight flights, with quarter-space landings at each angle, a newell post to support the handrail being placed at each bend (see Fig. 216).

Geometrical stair. The steps are arranged to follow the shape of the wall. The handrail is not broken by newells, but has an easy bend (known as a wreath), and is continuous (see Fig. 218.

Fig. 219 is a plan of a **Circular Geometrical Stair.**

Circular Newell Stairs, usually of spiral form, have a newell supporting the centre of the staircase.

The newell may be a separate column of masonry, or the newell may be worked on each step (see Fig. 220). It is usual to have an iron bar running up inside the newell to further strengthen the stair.

Steps are of varying form, **Tread and Riser** consisting of horizontal and vertical slabs of thin stone (see Fig. 221). They were largely used for basements, but have now been superseded by cast-iron treads and risers and concrete steps.

Marble is used as treads and risers for lining concrete steps in fine buildings (see Fig. 222).

Rectangular or **solid steps** are not used extensively for several reasons (see Fig. 223).

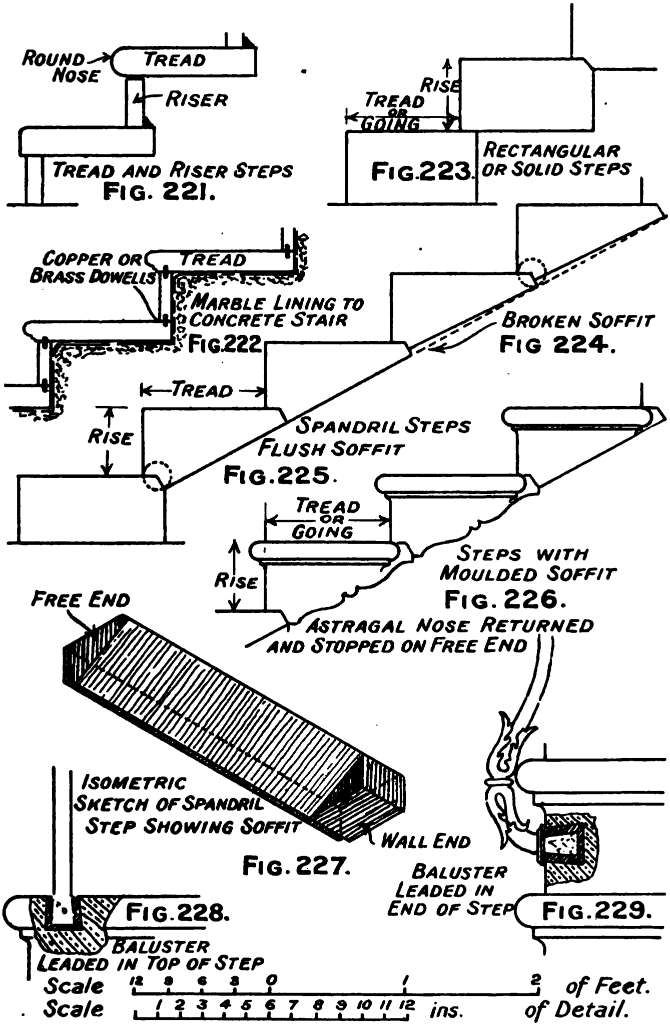
1. The projection on the soffit is unsightly and lessens head-room.

2. When properly worked with birdsmouth rebated joints are both expensive and cumbersome.

3. Concrete is rapidly superseding all forms of stone stairs.

Spandril steps may be finished in several ways. They are often cut one out of another from a rectangular stone, but the best type are worked with a horizontal seating at the wall end (see Fig. 227). They are often moulded on the front and at the free end (see Fig. 226), or arranged with **broken soffit** (Fig. 224), or **flush soffit** (Fig. 225). The undersides of the steps are occasionally moulded (see Fig. 226).

Steps are usually fixed after the building is erected. The space to receive them being filled in with bricks built in sand.



When steps are erected as the building proceeds, they should be protected from ill-usage. They should not be used

until properly set and safe, and should be covered with boards *fixed in position*, or the treads should have a course of tiles cemented on the surface, to be taken off at the completion of the building.

Steps should be carefully pinned into the wall with cement, and in brick walls a few courses of the brickwork, both above and below the steps, should be built in cement mortar.

Beds and joints should be as small as possible, and good tiles or slate should be used as material for pinning. The free ends of the steps should be supported by struts until the work is properly set.

Iron balusters are fixed into holes in the steps either with molten lead, sulphur, or sulphur and sand. When lead is used it should be properly caulked by being compressed with a blunt tool. The holes should be undercut.

Figs. 228, 229 show balusters let in the tread and the free end of the step.

Masonry Joints.

Butt Joint is made by two plane surfaces abutting each other, and is usually made good with mortar (see Fig. 230).

Rebated Joints.—There are two forms of rebated joints—

(*a*) Where both stones are rebated (Fig. 231).

(*b*) Where only one stone is rebated (Fig. 232).

The first is used for landings ; but both are used for coping joints to exclude weather from the wall.

Dowelled Joint.—Dowells may be of either metal or slate. Holes are cut into the joint opposite each other and the dowell is inserted and run with cement. The dowelled joint resists lateral movement, and is used both for vertical joints and for horizontal bed joints for mullions and jambs (see Fig. 233, horizontal dowell ; Fig. 234, vertical dowell).

Cramps may be of metal or slate. Metal cramps vary very considerably both in shape and size, a small brass cramp of round metal bar 1½ inches long by ⅛-inch diameter being used to hold venty marble together, to a cramp of either iron or copper 12 inches long by 1½ to 2 inches wide by ½-inch thick for heavy work. The purpose of the cramp is to draw and hold the joint together.

A sinking should be made in the stone so that the cramp sinks below the level of the surface, and the cramp should fit tightly at those points marked BB (Fig. 236). The cramp

should be tapped into position, and, fitting tightly at the points marked BB, should draw the abutting joint surfaces closely

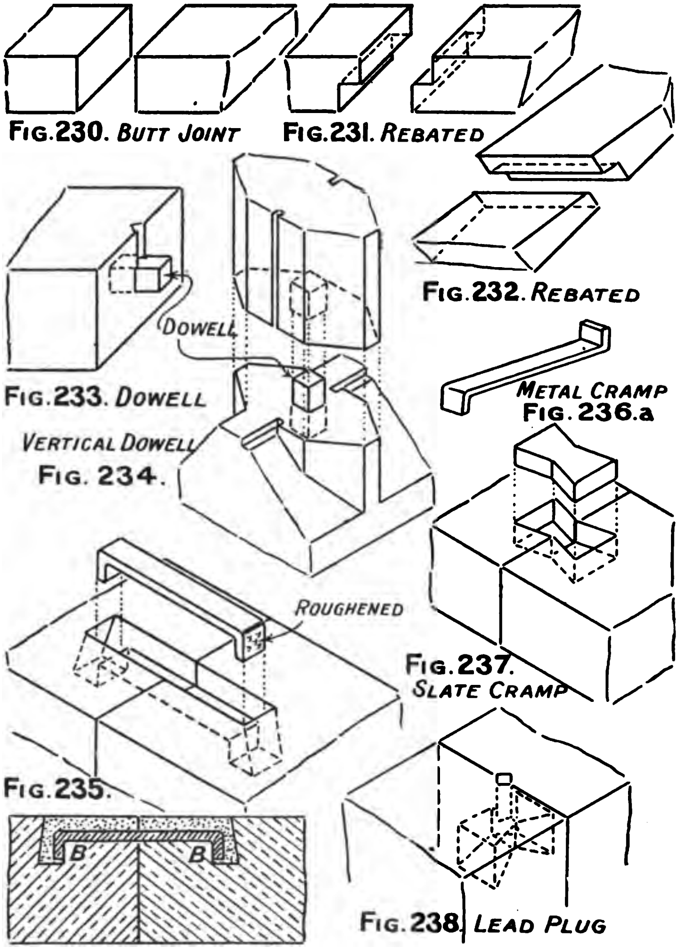


FIG. 230. *BUTT JOINT*

FIG. 231. *REBATED*

FIG. 232. *REBATED*

FIG. 233. *DOWELL*

VERTICAL DOWELL FIG. 234.

FIG. 236.a

FIG. 237. *SLATE CRAMP*

FIG. 235.

FIG. 238. *LEAD PLUG*

FIG. 236. *METAL CRAMP*

together. The remaining space is then filled with lead or Portland cement.

Fig. 235 is a rough isometric sketch showing the cramp

ready to be placed in position. Fig. 236A shows a cramp, which may be of round metal, that is chiefly used by marble masons for cramping marble linings to the wall. The tang of the cramp turning upwards enables the mason to properly point up the hole in the wall after the cramp is in position.

Fig. 237 illustrates a slate cramp, and consists of a piece of slate from ½-inch to one inch in thickness dovetailed and let in either flush or just below the face of the stone. The cramp should be bedded into position with Portland cement.

NOTE.—When iron or steel is used for cramps, dowells, or other purposes in building work, they should be treated with some preservative to prevent oxidization. **Galvanizing, sherardizing,** or a covering with **Dr. Angus Smith's solution** are all suitable methods.

Many fine buildings have become unsightly owing to the corrosion of these metals. The iron rusts and expands, and large pieces of stone are burst from the face of the building. The above processes should take place (*after made*), as the least crack in the covering will allow the iron to rust. Copper is the best metal for cramps and dowells, but is expensive.

Lead Plug.—A dovetailed recess is cut into each abutting joint surface, a chase is cut in each surface to the recess, and molten lead is poured into the channel thus formed (see Fig. 238). The recess should not be cut upwards, as the space would not be filled with lead, and is therefore a source of weakness.

JOGGLE JOINTS

Cement joggle is formed by an indentation being cut into the adjacent joint surfaces, so that when placed together a

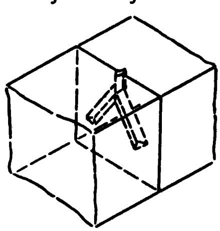


FIG. 239.—CEMENT JOGGLE.

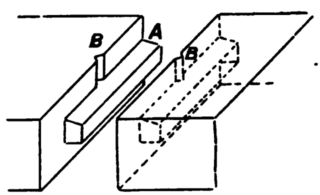


FIG. 240.—LANDING JOGGLE.

cavity is formed into which Portland cement grout is run. This is one of the most common form of joints in use, and is used for all purposes to resist lateral movements. Fig. 239

illustrates a cement joggle, but the shape of the indentations varies to a large extent. Pebbles are sometimes dropped into the cavity; but are quite unnecessary if the joggle is properly cut and grouted.

Landing Joggle.—A projecting tongue A is worked on one side of the joint, and a mortice is cut into the abutting stone to receive it. Clearance should be allowed both for easy fitting and also for the cementing material. A small chase BB is cut into each abutting surface of the joint, and molten lead or Portland cement grout is run into the joint when in position. The tongue and indentation are not cut to the front edge of the stone, which shows a plain butt joint (see Fig. 240).

Lintel joggles and **secret joggles** are shown in Figs. 124, 126, 127, 129, 130.

Table joint is an old form of joint, and was much in favour for heavy engineering work. It is very expensive and not often used (see Fig. 241).

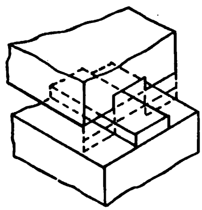


FIG. 241.—TABLE JOINT.

There are many other complicated and expensive joints used in masonry; but not in general use.

DETAILS

Copings.—Copings are placed on the top of walls to prevent water soaking into the wall from the top. They are of many and varying shapes; but usually project beyond the surface of the wall, and are provided with grooves on the underside, known as **throats**, to prevent the water running back on to the wall. When the top and bottom surfaces are parallel a slight tilt should be given to the coping to throw off the water.

Fig. 242 shows the top edge weathered, and is known as **feathered edge**. Fig. 243 shows the top weathered both ways, and is known as **saddle back coping**.

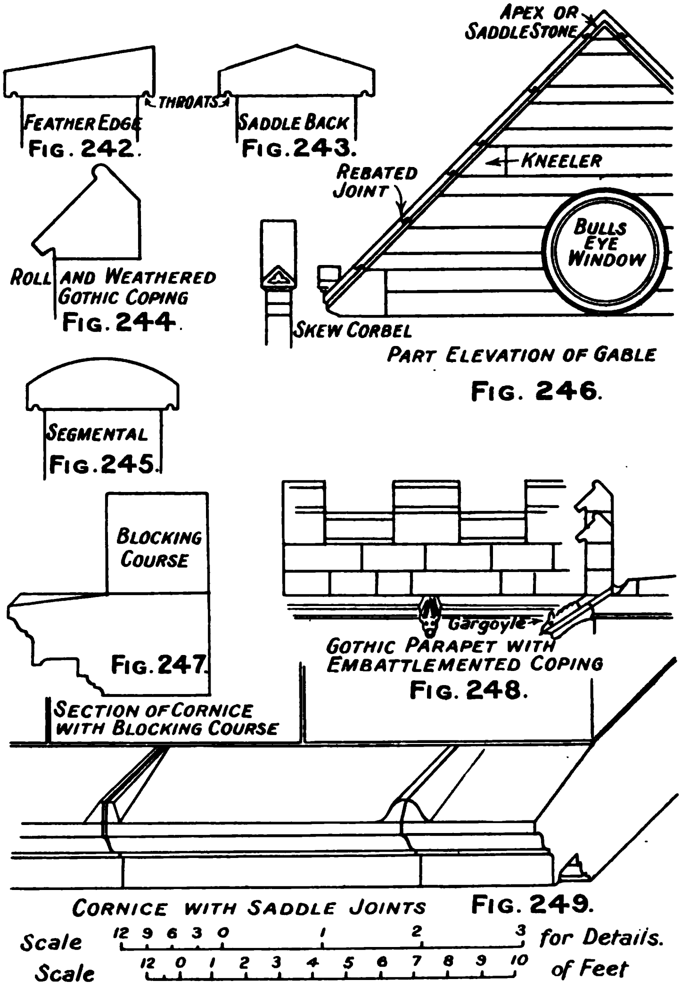
Fig. 245 shows a curved top, formed by the segment of a circle, and is known as **segmental coping**.

Fig. 244 shows a roll and weathered coping much used by the mediæval masons.

Fig. 248 shows an embattlement coping.

Fig. 246 illustrates a rebated coping fixed on a gable wall. Some means must be adopted to prevent the coping sliding

down the wall, and bond stones are used and known as **kneelers.**



The kneeler at the bottom of the gable when projecting or corbelled from the wall, is known as the **skew corbel.**

Cramps should also be used to further secure copings to gable walls.

The top stone of the gable is known as the **apex** or **saddle stone**.

Parapet is a dwarf wall in front of a gutter. Fig. 248 shows a Gothic parapet and gutter, with a stone water spout from the gutter, known as a **gargoyle**. Gargoyles in mediæval work were usually formed of carved heads of animals and grotesques.

Cornice.—A cornice serves the same purpose as a coping, and is arranged to protect the wall from rain. The cornice should be weathered on the top, and the parts at the joints should be left raised to prevent water soaking between the joints. These raised portions are known as **saddles** or **saddled joints** (see Fig. 249). The cornice is usually surmounted by a **blocking course** to assist in weighting the stone on to the wall and to prevent the cornice overturning (see Fig. 247).

CHAPTER V

ERECTION AND FIXING

Scaffolding is a staging erected during the progress of the building, to enable the workmen to economically execute their work. For ordinary rubble walls poles known as standards are raised at about eight feet apart. Ledgers are horizontal poles tied from standard to standard which support the putlogs, horizontal cross members, which are wedged into holes in the wall, and in their turn support the scaffold boards. When the face of the building is of wrought stone, putlogs cannot be fixed into the wall, and a separate series of standards are erected close to the wall, with ledgers to support the other end of the putlogs. Such stagings are known as independent scaffolds, and are held to the building through the various window openings. Scaffolds, are further braced, by poles and struts crossing the standards and ledgers diagonally.

On large buildings, in big towns, it is usual to build a very strong and substantial staging of more or less wrought timbers, at the height of the first floor. The clerk of works and foreman's offices are usually placed on this staging, as the most convenient place for inspecting materials as they are delivered from works. It also serves as a place to store materials for the external walls. This is known as a **gantry**.

Where heavy stones are to be hoisted, different types of machinery is in use.

1. In confined sites this usually consists of three high towers surmounted by a staging upon which is erected a **derrick crane**.

2. Steel rails are laid along the frontages of the building, and steel framed towers, supplied with electric and steam hoists, are used for hoisting and placing the stone in position. Where steel framed buildings are erected, outside scaffolding is sometimes omitted, and the walls are built **overhand**. This is an American practice, and has not found much favour in England.

Centres.—Arches are temporarily supported on wood bridging pieces known as **centres.** Small arches only need a piece of wood cut to the soffit of the arch. Larger arches require framed centres to support the voussoirs during erection, the centres being supported by props or struts from the cill below. Suitable folding wedges are placed between the struts and the centres, to facilitate their removal when the arch is set.

Hoisting.—Heavy stones are hoisted into position with the aid of lewises. Dovetailed holes are cut into the top bed and the lewis is inserted, the chain hook is attached to the ring of the lewis and the stone is hoisted to the required position.

Fig. 256 is an illustration of the most common form of lewis in use. It consists of wedge-shaped pieces of iron with a centre parallel piece. All of these members are holed at the top to take the pin P. The shackle S is placed over the top and the pin placed in position and keyed at K with a linch pin.

Great care should be exercised when fitting the lewis into the stone to see that it grips or bites at the bottom of the hole and not at the top. The lewis should be quite clear from the top of the hole (see figure).

Fig. 257 shows a chain lewis. Fig. 258 shows another form of lewis. Fig. 259 shows an under-water lewis.

After the stone is placed in position the lewis is released by pulling the line L and removing the key K.

In hoisting all heavy stones by means of lewises, the force should be exerted gradually and not in jerks. A jerk is likely to flush the stone at the lewis hole, and let it down.

Light and easily handled stones are raised to their position in a skip. The skip is a box having a bottom and two sides, to which the chain is slung. Several stones are packed in the skip and hoisted at the same time. The skip has the advantage of lessening the chance of fracture due to frequent handling, as the stone can be packed in the skip at the works, transferred to the job and hoisted right into position, where it may be unpacked under the supervision of the fixer.

All stone should be thoroughly cleaned and wetted before being bedded, to prevent the stone absorbing the moisture from the mortar before it has had time to set.

Mortar.—Mortar is made by mixing lime, sand and water, lime mortar ; or cement, sand and water, cement mortar, or cement compo. The strength of rubble masonry largely depends upon the quality of the mortar used in construction. It should therefore be composed of a good hydraulic lime, such

as blue lias, or preferably Portland cement. Mortar composed of either of these ingredients will be both tenacious, and when set, hard and durable.

Sand is used in mortar chiefly for economy, the sand forming an aggregate about which the liquid lime or cement sets and adheres. The sand should be sharp and angular, having facets to which the matrix may key; it should be free from dirt, clay and other foreign substances. Pit sand, when carefully washed, is more angular and better than river sand, but good river sand is usually cleaner, and makes good mortar if the grains are not too rounded and polished. Smooth and rounded sand may be detected by the feel, and dirty sand usually stains the hand. Sea sand is not suitable for building work owing to its salinity, the salts attracting moisture to the joints, causing dampness and efflorescence.

The water used for making mortar should be clean and free from dirt and vegetable matter. Salt water will have the same effect as sea sand, and should not be used.

Sand may be mixed with cement in the proportion of two to one, to four to one. The smaller the proportion of sand the better the mortar. A good and satisfactory mortar is made with three parts of clean sharp sand to one of good hydraulic lime, or one of Portland cement.

It is very important that the sand and cement is thoroughly mixed together when dry, and it should be turned over two or three times in its dry state. This mortar should be used immediately after the water is added, and only sufficient mortar should be made that can be used in the course of a few hours. Cement or hydraulic lime mortar should never be mixed (knocked up) a second time.

In walls built of wrought stone it is not so essential that mortar is hard and tenacious, the chief object of the mortar being to keep wet out of the beds and joints, and to form a seating for the stone.

It is preferable to bed the stone so that the beds are left open for about $\frac{3}{4}$ of an inch from the face, to prevent flushing or splintering of the stone due to imperfect bedding. The joints so left may be pointed with mason's putty when cleaning down.

Mason's putty is composed of well-slaked lime, carefully screened of small lumps and overburned particles, and stone dust in about equal proportions. The mixture, with the addition of sand, is often used for bedding stones, but the

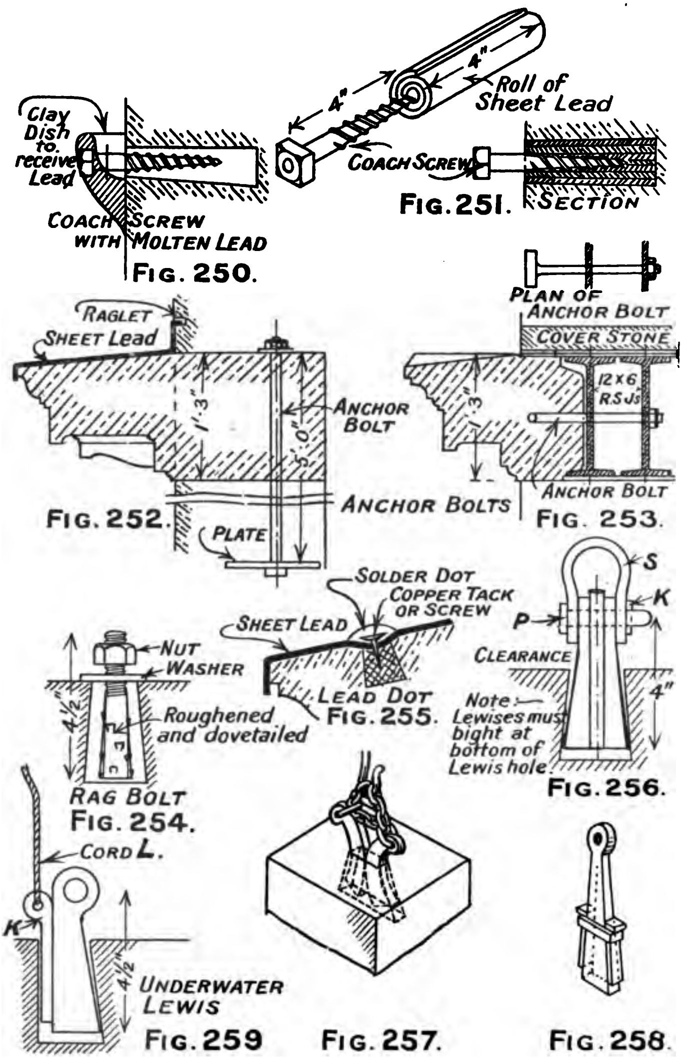


FIG. 250. FIG. 251. FIG. 252. FIG. 253. FIG. 254. FIG. 255. FIG. 256. FIG. 257. FIG. 258. FIG. 259

practice is not a good one, and the putty in the interior of the bed seldom sets.

The lime is dependent upon the chemical action set up by

combination with the carbonic acid in the air, and only the outer casing is acted upon, forming an air-tight skin, and keeping the material at the interior of the bed in a plastic state.

The sand to some extent forms small channels or ducts ; but hydraulic lime and Portland cement is so easily obtained and perfectly manufactured, that it is better to use them for bedding and jointing.

Grout is made from neat Portland cement and water. It does not set so hard as cement mixed with a less quantity of water, and should not be made too thin. Grout is used for flushing up joints, and also for filling in the joggles cut in joints.

The practice of working beds hollow, or of bedding the stone hollow, cannot be too strongly condemned. Hollow beds, whether worked on the stone or produced by the mortar, causes the weight to be transferred to the edges of the stone, resulting sooner or later in spalling (see Fig. 261).

The same bad effect results when stone is worked " lean " at the back and is packed with slate or sheet lead.

Where walls have battered or sloping faces, it is preferable

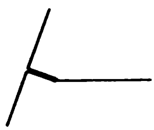


FIG. 260.

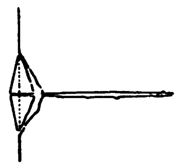


FIG. 261.

to have the bed worked normal to the face for a short distance (see Fig. 260).

Fixing Iron to Stone.—*Rag bolts* or *lewis bolts* are often used for fixing iron and steel to stone. The bolt consists of a piece of iron roughened and dovetailed at one end, the other end being screwed with a whitworth thread to receive a nut. An undercut hole is worked in the stone to receive the roughened end of the bolt, which is cemented into position, or run with molten lead (see Fig. 254).

It is sometimes necessary to use a bolt than can be easily removed, in which case a coach bolt or coach screw is leaded in position. When the screw is fixed in a vertical wall, it is necessary to fix a clay cap or dish on the wall, to direct the lead into the hole. The clay should project above the top of the hole, so that the hole may be filled with lead (see Fig. 250).

A very satisfactory method of fixing a coach screw to a wall is shown in Fig. 251. A hole is cut in the wall, slightly undercut as before, and a small roll of sheet lead is placed in position. The lead should be tightly rolled, and should just fit the hole cut to receive it. A small hole is started in the centre of the lead with a punch, and the coach screw spannered home.

Fixing Lead to Stone—Raglet.—Sheet lead is fixed into a groove cut in the stone, known as a raglet. The sheet lead is wedged to the raglet with pieces of lead and finally pointed with cement. The lead is sometimes caulked right along the raglet.

Lead dot; sheet lead is also fixed to stone by means of a lead dot. An undercut hole is made in the stone and filled with lead. The top of the hole is dished and the sheet lead is dressed into the dish and screwed into position. The top of the hole is then filled up with solder and molten lead (see Fig. 255).

In all cases where molten lead is run into stone, care should be exercised—

1. To see that the hole is properly cleared of stone dust.
2. That there is no water or moisture in the hole.
3. That after running with lead it is properly caulked and compressed into all interstices caused by the contraction of the lead in cooling.

Anchor Bolts.—Where heavy overhanging cornices are placed on buildings, they should be carefully strutted up, until sufficient weight is placed on the top to hold them securely. Where only light walls and blocking courses are placed on top, it is advisable to use anchor bolts to hold the cornice in position. Fig. 252 shows one form of anchor bolt. When facing girders with stone, it is often necessary to fasten the stone to the steel work.

Fig. 253 shows a method for anchoring a cornice to steel joists. The anchor bolt is formed of round iron in the shape of a tee, the other end being screwed to receive a nut. Holes are drilled in the joists and the bolt is placed in position. The stone is then slid up to the bolt, the joint being holed to receive one arm of the tee, which fixes into the stone, in a similar manner to a dowell. The nut is then spannered up until the stones are held tight.

The stone may be further secured by cramps let into the stone and passed over the flange of the girders, which they clip on the inside.

Cover Stones.—When small stones are to be bedded on the top of girders, especially if they are riveted, cover stones, taking the whole thickness of the wall, should first be laid on the girders. Cover stones should be of hard Yorkshire flagstone 2½ to 4 inches thick. They spread the resistance of the girders over the base of the wall.

Templates or **Padstones.**—The ends of all girders, whether of wood or iron, should be placed upon hard stone templates. The templates are to distribute the weight transferred from the girder to the walls over a larger area, and vary in size and thickness according to the weight that is placed upon them.

Cleaning Down.—The faces of all stone should be cleaned and covered with slurry before erection. Corners, angles, noses of strings and cornices should be protected by wood or other covering during erection. When the carcase of the building is complete, this slurry is cleaned off and the protection taken down.

Weathering to cornices which is sometimes left to protect the nose from damage is worked off, stools for moulded jambs and mullions are worked in cleanly, and any damage that may have happened during erection, repaired; joints are pointed with putty and everything made good, the whole of the process being known as **cleaning down.**

CHAPTER VI

MATERIALS—BUILDING STONE

STONE requires very careful selection, and it is to be regretted that those responsible do not always give this important building material the consideration it deserves.

The few notes included in this chapter are by no means exhaustive : but it is hoped that they will serve as a guide in selecting suitable stone.

A complete knowledge cannot be obtained by reading books. The student should examine buildings that have been erected, and note the condition of the stone. He should also carefully consider the position in which the stone is placed in the buildings, and make sure that the stone used, is the reputed stone, and not a *substitute*.

Probably the most important items to consider when selecting stone are :—

1. **The position it is to occupy in the building, and its purpose.**
2. **Climatic conditions.**
3. **Situation of the building.**
4. **Whether blocks of suitable size and in sufficient quantities can be obtained.**
5. **The general characteristics of the stone.**

1. **The Position it is to occupy in the Building, and its Purpose.**—Soft and fine grained stones, which are eminently fitted for interior carving, may be utterly unsuited for exterior work.

Coloured marbles largely used for interior decoration, are quite unsuited for exterior work in England.

Soft freestones are not suited for paving, whilst laminated micaceous flagstones are unfitted for work requiring a great amount of labour.

Plinths, quoins, and all those portions of a building likely

to receive rough treatment, should be built of hard and sound stone.

Copings, cornices and other projecting members, which are likely to be in a state of saturation through rain and weather influence, should be specially selected.

Curbs for roads, harbour and dock walls, and all work likely to be subjected to rough usage, require to be of hard and intractable stone.

Templates and cover stones should be selected for their resistance to crushing.

2. **Climatic Conditions.**—In dry climates stone is found to weather better than in wet or humid climates.

In Southern Europe, Egypt, India, and Central America, there are many examples of ancient buildings and monuments still in existence, where stone of a comparatively soft nature has been used, and is still in a perfect state of preservation.

In the British Isles, which have a humid atmosphere, stone is specially liable to decay, and careful selection is of the utmost importance.

Change of temperature, causing expansion and contraction, and the opening of minute and natural cracks in stone, is often cited as a cause for the decay of stone. Such expansion and contraction cannot be great, and the resultant damage slight.

Rain, especially when accompanied by a high wind, has a most damaging effect on stone.

The stonework on the south and south-west sides of a building, is found to decay more rapidly than stone sheltered from these driving rains.

Noses of cornices, drip stones, gargoyles, which are all more or less subjected to running water during a storm, are found to decay more rapidly than stone placed in a more sheltered position.

A gentle wind has a beneficial effect, drying out the contained moisture.

Frost is another great damaging force, and porous stones suffer severely, the moisture in the pores of the stone freezing, expanding, and displacing particles of stone, causing ultimate disintegration.

3. **Situation of the Building.**—Stone buildings erected in manufacturing towns are more liable to decay than buildings erected in the country. The air, charged with sulphurous, hydrochloric, and other acids, has a most deleterious effect on

stone that contains carbonate of lime or carbonate of magnesia. Rain, charged with acid, is driven into the pores of the stone and rapid disintegration results. Sun, and a gentle wind, has the effect of drying out the moisture, when the acid has not such a damaging effect.

In sea walls and harbour works, a mollusc has been found that bores holes in limestone and sandstone ; but granite has been found to withstand its attacks.

Fire has a most destructive influence on stone, marble or granite.

4. In selecting stone for building purposes, it is necessary to know the *depth of the bed* of the stone, the *largest size* and the *average size* of the blocks quarried. Inquiry should also be made as to the quantity the owners can supply in a given time. The oversight of this factor has caused considerable trouble during the erection of a building.

Care should be taken to specify which bed the stone is to be taken from, as stone not only varies considerably in the same district, but also in **the same quarry.** This variation in quality of stone from the same quarry is sometimes abused, the softer bed being substituted for the harder.

It is not surprising that foremen and managing masons, whose first consideration must be to make the work pay, often select soft stone for those parts of the building requiring most hand labour, whilst relegating the hard and ofttimes best stone to ashlar.

It must be remembered that mouldings, cornices, and all projections have to withstand the greatest weather influence.

5. **General Characteristics of Building Stone.**—The durability of stone largely depends upon

(*a*) **Physical structure.**

(*b*) **Chemical composition.**

Physical Structure.—All stones are more or less porous ; but the less porous stones are more likely to resist the action of the weather. Porous stones containing lime are affected by the rain impregnated with acid, especially in smoky towns, soaking into the pores and dissolving the lime or magnesia, causing ultimate destruction.

Porous stones are also affected by frost, the smaller the pores the greater the danger.

Stone with large pores does not retain moisture for such a long period as stone with small pores, and for this reason is not so readily affected by either acids or frost.

The *density* of a stone affects its durability to a large extent, close and compact stones resisting saturation. They are also much heavier, and likely to resist a greater crushing weight.

Compression.—The crushing weights given in the following tables are more or less unreliable, owing to the want of standardization of the size of the cubes crushed, the variation of the material from the same quarry, the ratio of increase of pressure exerted by machines supervised by different operators, and the means adopted to insure even and regular pressure over the crushing surface.

Crushing weights would be valuable, provided that standardized tests were made by a reliable and independent authority, with cubes of the same size and tested under precisely the same conditions. At least six cubes should be tested from the same quarry, and the results tabulated. The information would provide us with valuable data as to the weathering properties of a stone, considered in conjunction with other factors.

Colour and Appearance.—Highly coloured stones indicate the presence of a large percentage of iron, which would not only cause rust stains on the face of the building, but would probably lead to rapid decay.

Stones of mottled appearance should also be carefully examined. The mottled colour may be due to variation in the chemical composition, resulting in unequal weathering.

Stone should also be free from clay holes, cracks, vents, or shakes. It should break cleanly and show up sharp and bright at the fracture: a muddy and dirty appearance indicates that the stone would be liable to weather badly.

Natural Bed.—The natural bed is the surface upon which the stone was **originally** deposited. The bedding planes may be inclined in the quarry.

The bed cannot always be detected away from the quarry, and for this reason all blocks should be marked indicating the bed, before they leave the quarry.

All stone, especially that of a laminated nature, should be fixed in the building with the beds horizontal, or at right angles to the axis of pressure (see Fig. 265). In arches the beds should be parallel to the centre line of the voussoir (see Fig. 264).

Provision is often made for laying cornices with the planes of stratification vertical and at right angles to the face of the

wall, thus to some extent protecting the undercut nose (see Fig. 263 and 262).

In such case the top of the cornice should be covered with lead or asphalte to prevent rain soaking between the beds. The

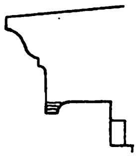


FIG. 262.

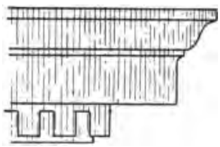


FIG. 263.

quoin stone, however, must be laid on its natural bed and must be specially selected.

The writer considers that it would be preferable to specially select the stone for cornices and lay it on its natural bed—

Firstly, to avoid unequal weathering of the quoin stones; return stones, and breaks, that occur in buildings.

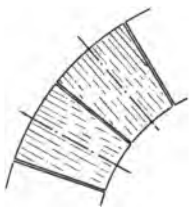


FIG. 264.

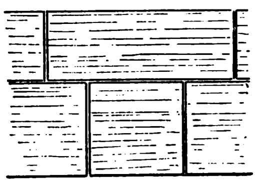


FIG. 265.

Secondly, stone when laid on its natural bed is able to resist a greater crushing weight.

Seasoning.—All stone when first quarried contains a certain amount of moisture, known as **quarry sap,** and for this reason is more easily worked when first quarried.

The drying out of the quarry sap induces the stone to harden, and after it is worked it should be stored under cover to season.

Stone should never be stored on the damp ground, but should be raised on blocks to prevent moisture rising from the floor. Spaces should be arranged between the blocks to allow a free passage of air to pass between, and frost should be excluded. If stored in the open; a rough cover should be placed over the top to exclude rain, and straw should be placed over the worked stones to prevent damage from frost.

Tests for Building Stones

Chemical Tests.—A little hydrochloric acid dropped on a clean fracture will denote the presence of carbonate of lime or magnesia. The acid will freely effervesce on limestone, and less freely on sandstones containing small quantities of lime.

A few chips of stone immersed in a one per cent. solution of sulphuric and hydrochloric acid, will indicate how the stone is likely to weather in a smoky town.

If the solution is clear after two or three days, the stone is of good quality and likely to withstand the acid-laden atmosphere.

Absorption.—Stone should be immersed in water for twenty-four hours and careful note taken of the amount of water absorbed. Granites should not absorb more than 1 per cent. of their bulk. Sandstones should not absorb more than 10 per cent. Limestones not more than 17 per cent. of their bulk.

Weight.—The weight of a stone affords a guide as to its density, the heavy stone being usually the better weathering. Crushing weight considered in conjunction with other factors serves as a guide.

Stone should break with a clean and sharp fracture, and the particles should be bright and well defined, a muddy appearance indicating that the stone is not likely to weather well. The best test for durability is the examination of existing buildings, where the stone has been used, both in the neighbourhood of the quarry and in towns.

The exposed sides of an old quarry or pieces of the stone lying around, should give a fair indication as to its weathering qualities. Care should be taken that the stone inspected is from the reputed quarry and also from which bed.

Classification

Stone is often classed under three divisions—

Igneous.—Rocks formed in a state of fusion, sometimes of volcanic origin, including **granites, syenites, porphrys,** etc.

Aqueous.—Sedimentary rocks deposited from water or air. Most of the **limestones** and **sandstones** used in building come under this heading.

Metamorphic.—Rocks of either of the above divisions that have been subjected to great heat, pressure, or both, causing

molecular change. **Marbles, slates,** and some **granites** are in this class.

The geologist further classifies them in accordance with their stratagraphical position or geological age. The practical classification is, however, probably the best for these few notes.

1. **Granite.**
2. **Limestone**
3. **Sandstone.**
4. **Marble.**
5. **Slate.**

Granites.—Granites are chiefly composed of *quartz crystals* (silica), *felspar*, and *mica.*

Syenites are composed of quartz, felspar, and hornblende.

Syenitic granite is composed of quartz, felspar, mica, and hornblende.

Quartz is practically indestructible, and the quality of the granite, therefore, is largely dependent upon the nature of the felspar and quantity of mica.

Felspar is of two distinct kinds—orthoclase =potash felspar, oligoclase =lime and soda felspar, and it is to this constituent that granite owes its colour.

Mica readily decomposes and therefore affects the durability.

Iron and manganese is present in most granites, and iron, if present in large quantities, is a cause of weakness.

The principal granite quarries in the British Isles are in Aberdeen and Cornwall. Granite is also found in Leicestershire and Guernsey, but it is chiefly used for road metal. Outcrops of granite also occur in many other counties and in Ireland.

The tabulated list on page 108 indicates the principal granites in use.

Limestone is composed of nearly pure carbonate of lime, either in grains cemented together with carbonate of lime, small egg-shaped shells cemented together by carbonate of lime (*known as Oolites*), or large shells and fossils cemented together by carbonate of lime and known as *fossil limestone.*

Limestones containing a large proportion of carbonate of magnesia, are known as *Dolomites.* Many limestones contain silica, bitumen, iron, etc. The durability of the stone depends largely upon its structure, the best weathering limestones being crystalline in texture.

Limestone varies very considerably in hardness, some stones being cut with toothed saws and smoothed with drags, whilst the hammer and punch must be used on others to reduce them

GRANITES

Name of quarry.	County.	Colour.	Weight in lbs.	Crushing strain in tons.	Remarks.
Cheesewring	Cornwall	Light grey	168·0	1440·3	Coarse grained, used at Westminster Bridge, Southampton, and Devonport Docks.
Colcerrow .	,,	Light greenish grey	168·0	1336·1	Coarse grained, used in Plymouth breakwater; Keyham, Chatham, and Portsmouth Docks.
Creetown .	Kirkcudbrightshire	Light grey	170·0	1633·0	Medium grained, used at Liverpool Docks.
Correnie . .	Aberdeenshire	Bright salmon	162·0	1284·0	Medium grain. Municipal Buildings, Glasgow.
De Lank . .	Cornwall	Light greenish grey	165·0	1171·0	Fine and close grained, used at Blackfriars Bridge, London.
Dancing Cairn	Aberdeenshire	Light blue-grey	171·0	—	Buildings in Aberdeen, kerbs in London.
Kemnay .	Aberdeenshire	Grey	161·0	1211·1	—
Lamorna .	Cornwall	Grey	168·0	—	Used at Devonport, Keyham, and other dockyards.
Mountsorrel	Leicestershire	Pinkish brown	163·0	2087·1	Medium grained.
Penryn . .	Cornwall	Light grey	165·0	1250·8	Coarse grained, used at Devonport, Keyham, Portsmouth dockyards, Portland breakwater, etc.
Princetown .	Devonshire	Light grey	165·0	—	Used in London Bridge.
Peterhead .	Aberdeenshire	Red	158·5	1470·0	Extensively used for monumental work. Coarse grained, used for pillars (highly decorative). Carlton Club, London; columns St. George's Hall, Liverpool.
Ross of Mull	Argyleshire	Pink, red, and grey	176·0	—	Coarse grained, Westminster Bridge, Albert Memorial, London.
Rubislaw .	Aberdeenshire	Grey	163·0	1289·0	Fine grained; buildings in Aberdeen.
Shap Fell .	Westmorland	Pink or reddish brown	160·0	1200·0	Coarse grained; columns St. Pancras Station, London; columns in Hull Museum.
Sclattie . .	Aberdeenshire	Grey	161·0	850·0	Close grained.
Tyrebagger .	Aberdeenshire	Grey	171·0	—	Fine grained, used for decorative work as well as building.
Tor . . .	Devonshire	Light grey	165·0	—	Known as "Tamar" granite, used for Plymouth breakwater.

to shape. They vary in colour from white to dark grey, cream, yellow, and brown.

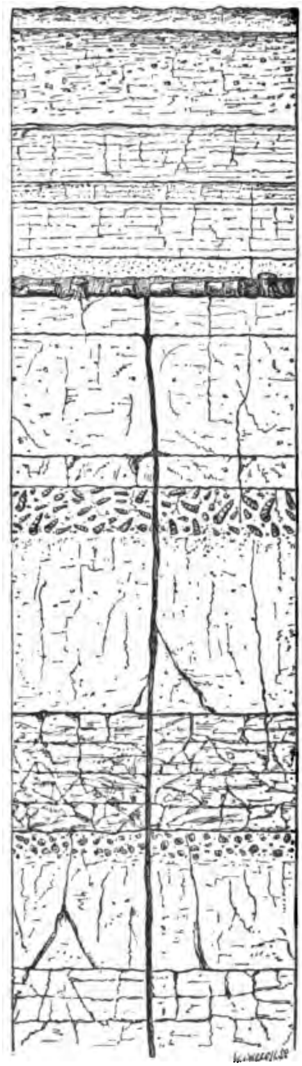


FIG. 266.—SECTION OF PORTLAND STONE QUARRY.

Dolomites are highly crystalline in texture, and many of them when carefully selected are excellent weathering stones.

Portland stone is an oolite, and is probably the best weathering limestone that is quarried in England. There are several different beds of Portland, and there is a great difference in the stone, not only from each bed but also from the different workings.

Fig. 266 shows a section of one of the quarries illustrating the position of the useful beds.

The first useful building stone is the *roach stone*, found in layers of from two to three feet in thickness. It consists of a large number of fossils cemented together by carbonate of lime. It is not suitable for finely moulded and carved work, owing to the fossils, and cavities left owing to the fossils having dropped out. It is mostly used for heavy engineering work, breakwaters, dock and harbour walls, or in any position where sharp arrises and good faces are not required. The roach stone contains a shell known as the Portland screw, which distinguishes it from the *basebed roach* or *curf* (see Fig. 267).

Cast of the shell known as the "Portland Screw," *Cerithium Portlandicum.*

FIG. 267.

Whitbed is found immediately beneath, and firmly attached to, the roach stone. It is of a whitish-brown colour, is hard and crystalline, and is the best bed quarried at Portland. It is fairly regular in texture, but has a few shells, especially near the cap end of the block.

Bastard roach or curf somewhat resembles true roach in appearance, but can easily be distinguished owing to the absence of the Portland screw. It is not often imported to other districts, but is used locally for general rough work. It does not weather very well.

Basebed is a much softer stone, found under the curf; it is whiter than Whitbed, and is called occasionally Whitebed or Bestbed. When broken, the fracture has not the crystalline appearance of Whitbed, being of finer and closer texture and generally dull. It does not weather so well as Whitbed, but is sometimes substituted and even selected for exterior work, owing to its finer grain, and the facility with which it is worked. Occasional flints are found embedded in this stone, pocketed in sand holes. These flints are sometimes of very large size.

Portland stone can be quarried in large blocks. It is

difficult to distinguish the bed of the stone, the expert often being deceived. For this reason it is not considered so important to lay the stone on its natural bed, although blocks are carefully marked at the quarry.

Portland stone is dressed with hard stone tools and mallet, and the faces rubbed.

Bath Stones (Oolites).—Bath stone is a general term describing those stones quarried in the vicinity of Bath. There are many different kinds of varying quality. The stone is tunnelled from the sides of the hills, some of the quarries passing miles under the hill and having different branch workings.

Bath stone is cut with a toothed saw and brought to a face with drags. Many of the stones are of fine even grain and are suitable for interior carving.

Box Ground, probably the best weathering stone, is quarried from the same tunnel as Corsham Down, and is used for dressings and other exterior work, for which it is well suited, except, perhaps, for manufacturing towns.

Corsham Down is softer and more regular in texture than Box Ground, but does not weather so well.

Farleigh Down is a much finer-grained stone and is well fitted for fine carving and interior work generally.

Monks Park is a fine close-grained stone of the Bath series.

Kentish Rag is a hard, close and intractable limestone, found in thin beds in the Kent districts. It is principally used for walling, bridges, etc., but is seldom used for dressings, owing to the difficulty in obtaining large stones and the expensive labour item in working. The stone is very compact and heavy dark grey and greenish grey in colour; weathers well.

Purbeck, a shelly limestone, quarried near Swanage in Dorsetshire. There are several different kinds, which are hard and used for pavings, steps, etc.

Purbeck Marble, a fossil limestone consisting of a mass of shells, is found in thin beds, takes a fine polish, and is much in favour for the shafts used in internal church work.

Caen Stone is an oolitic limestone quarried in Normandy. It has an exceedingly fine and even grain, is light cream in colour, and is very valuable for interior carvings owing to the facility with which it is worked, and the fine and sharp arrises that can be obtained. It was largely used by the Normans for exterior work, but it is not suitable for exterior work, being so

very porous (fine pores), and when broken has a somewhat muddy appearance.

Hopton Wood is a fossil limestone quarried in Derbyshire. It varies considerably in colour, from a light speckled cream to dark and foliated shades of light brown and grey. It is capable of taking a very high polish and is eminently fitted for interior decorative work.

Alabaster or *Gypsum* is composed of sulphate of lime and is found in several districts in England. It is of a translucent white with veins and patches of rich brown or grey. It is capable of taking a high polish and is suitable for interior work. When sound it can be cut into very thin slabs, and is now very effectively used as screens for electric lamps. When turned as vases and suspended from the ceiling, the glare from the lamps is hidden, whilst the colouring and the veining of the alabaster, is illuminated to the greater advantage.

Small nodules and gypsum of inferior quality are calcined and ground for plaster of Paris.

Magnesian Limestones.—Dolomites are highly crystalline in structure, and when carefully selected suitable for all exterior work.

The commissioners selected a dolomite for the Houses of Parliament, and the decay of that building was not due to the stone selected, but to the want of supervision. No effort of any kind was made to supervise the stone sent from the quarries, and material was sent indiscriminately, any of the beds being used, and no care was taken to see that the stone was placed on its natural bed.

Bolsover Moor, quarried in Derbyshire, yellowish brown in colour, fine grained, and a durable building stone.

This was the stone that was first selected by the Royal Commission for the Houses of Parliament, but it was afterwards found that the supply was not sufficient, and *Anston*, a light cream-coloured dolomite quarried a few miles from the Bolsover quarries, but situate in Yorkshire, was used.

Anston was used for the erection of the Geological Museum, Jermyn Street, London, erected about the same time as the Houses of Parliament, but in this instance the stones were carefully selected, and the building is in a good state of preservation at the present time.

Mansfield Woodhouse, a yellow dolomite, quarried at Mansfield, Nottinghamshire, is a fine-grained stone capable of receiving a fair polish. Is suitable for internal work. Red and

White Mansfield, magnesian sandstones are also quarried in the neighbourhood, Red Mansfield being a very durable sandstone which should be carefully selected. It is essential that this stone is laid on its natural bed, which may be easily discerned by the thin layers and markings of the beds. White Mansfield is more fitted for internal work.

Sandstone is composed of grains of silica (sand) cemented together by silicic acid, carbonate of lime, carbonate of magnesia, alumina, or other minerals either singly or in combination. Other minerals are often present in the form of iron, mica and clay.

The grains of silica are imperishable and the durability of the stone therefore depends upon the cementing material. When the matrix is composed of grains of carbonate of lime cemented by silica, the grains are liable to decay, leaving the siliceous cement in a very porous form.

The stone varies in colour from white to yellow and brown, red, green, blue, grey, and even black. The colour is mainly due to the presence of iron in one of its forms.

Sandstones are found in most of the geological formations from the Cambrian to the Tertiary. This classification would, however, be out of place in this chapter.

Hard York stone is a generic term, not even describing stone from Yorkshire; and some further description or better specification is necessary for exact definition. There are, however, so many quarries in Yorkshire, Lancashire, and the surrounding districts supplying stone of similar character, that it is only possible to give but a few of the chief varieties.

Bramley Fall is a coarse-grained sandstone, quarried near Leeds, very durable and specially suitable for heavy engineering work. It is light brown in colour, and there are several quarries supplying a millstone grit known by this name.

Cragleith is a very hard and durable sandstone, very pale grey in colour, containing small specks of mica. It is quarried near Edinburgh and is probably the best sandstone in the kingdom. There are, however, many quarries in the district supplying stone known as Cragleith.

Hailes is a sandstone quarried in the same district, of which there are several varieties.

White Hailes is a fine close-grained sandstone with a greyish tint. It is probably the best weathering of the Hailes stone.

Pink Hailes is a micaceous fine-grained sandstone quarried

in the same district. It is much used in Edinburgh and is a very durable stone.

Blue Hailes is a micaceous sandstone, slightly coarser in grain than the pink. It is light grey in colour, with fine beds of carbonaceous and micaceous matter.

Darley Dale is a millstone grit quarried in Derbyshire, light brown in colour and having specks of mica uniformly spread through the stone. It is compact, close-grained, hard and durable. There is more than one quarry supplying stone known as Darley Dale.

Howley Park, a light brown, fine-grained stone, quarried at Morley, Yorkshire. It is chiefly used for copings, and sometimes as landings and steps, but it is not so hard as some of the stones from this district.

Silex Hard York Stone, fine-grained, drab-coloured sandstone, quarried near Halifax, Yorkshire. It is very hard, practically non-porous, and stands a great crushing weight. It is eminently fitted for landings and steps, for which it is used.

Other stones will be found in the tables on pages 116–119.

Marble is a crystalline limestone that has undergone metamorphic action. It is generally understood as a limestone capable of receiving a high polish, and serpentines, breccias, and even alabaster and limestones, are often included under this heading.

The chemical composition varies to a large extent; but they consist largely of carbonate of lime with metallic oxides, shells, corals, and other accidental substances to which their colouring is due.

Many marbles are beautifully veined and marked, and are now used to a very large extent for interior wall linings and decoration.

The marble found in England and Ireland is not so popular as it should be, most of the marble used in England being imported from the Continent.

The chief marble quarries in the British Isles are in Devonshire, Derbyshire, Argyleshire, Sutherland, and Kilkenny in Ireland.

Slate is a clayey rock, compact and fine grained, having planes of cleavage not necessarily coinciding with the bedding planes. These planes of cleavage have been caused by metamorphic action and are due to great lateral pressure. When these planes of cleavage coincide, or nearly so, with the bedding planes, the slate is difficult to split, and is then sawn and used

for paving, cistern slabs, electric switch boards, and many other purposes.

The colour of slate varies from blue-black to purple, grey and green. A good slate should be practically non-absorbent, and when split into thin slabs is well fitted for a light roofing material.

The chief quarries are in Wales, Westmoreland, Cumberland, and many other districts.

PRESERVATION OF STONE

Many methods have been tried from time to time to prevent the decay of stone. They may be divided under two headings—

1. To cover exposed surfaces and to fill the pores with some organic substance.

Boiled linseed oil has been tried with some success, but it has the disadvantage of discolouring the stone, and it requires periodical renewal, as it is itself subject to decay. Paint is one of the most common methods, but it has the same disadvantages as oil, and it absolutely destroys the appearance of the stone. Paraffin, paraffin and wax, turpentine and wax, have been used, but they are all open to the same objection.

2. To cover the surface of the stone with a solution that will crystallize in the pores and form an impervious surface, or a solution that will chemically combine with the stone and form a more durable compound.

Fluate supplied by the Bath stone firms is probably the most well known in the trade. It is supplied in the form of crystals, which must be dissolved in water and applied to the stone with a brush. The solution chemically combines with the stone and hardens the face. In covering old work, care must be taken to see that the stone is thoroughly clean, and when applying the solution to see that it does not run down the face of the wall. The texture and appearance of the stone is not injured in any way.

LIMESTONES

Name.	County.	Colour.	Weight in lbs. per cub. ft.	Crushing strain in tons per sq. ft.	Absorption. Per cent.	Geological series.	—	Remarks.
Ancaster . .	Lincolnshire	Cream	135·3	218·6	6·27	Jurassic	96·34 c. of lime, 2·15 c. of magnesia	Fine grained, suitable for dressings.
Ancaster weather bed.	„ same quarry	Light brown	156·3	552·6	2·42	„	—	Hard and compact, suitable for quoins, plinths, and is a good weathering stone.
BATH STONES	—	—	—	—	—	—	—	All the BATH STONES are much used for church work.
BOX GROUND	Wiltshire	Cream	129·0	107·0	7·75	„	94·52 c. of lime, 2·5 magnesia, 1·2 alumina and iron	Coarse grained, good weathering stone, has irregular beds and shells.
CORSHAM . .	„	Light cream	129·0	128·0	11·18	„	As above	Fine grained regular stone, suitable for dressings, etc.
COMBE DOWN	Somersetshire	„ „	128·0	151·0	6·0	„	As above	As above.
FARLEIGH .	Wiltshire	„ „	120·0	62·0	13·13	„	—	Fine grained, suitable for interior fine carving.
MONKS PARK	Somersetshire	Cream	137·0	223·5	7·51	„	97·2 c. of lime, 1·0 silica, 1·6 alumina and iron	As above.
HARTHAM PARK	Wiltshire	Deep cream	123·5	—	—	„	—	Suitable for dressings, etc.
STOKE GROUND	Somersetshire	Light brown	126·0	107·0	10·52	„	—	As above.
Beer	Devonshire	White	131·7	151·2	—	Cretaceous	—	Suitable for interior work, fine grained but somewhat irregular and knotty.
Caen	Normandy	Light cream	168·0	198·0	—	Jurassic	Unsuited for outside work	Excellent for interior work.
Casterton . .	Rutlandshire	Cream	129·0	—	—	„	—	Dressings, sharp arrises cannot be worked in this stone, owing to its roe-like nature.

Clipsham . .	Rutlandshire	Cream	150·0	291·6	—	Jurassic	97·5 carbonate of lime	Dressings and general building.
Chilmark . .	Wiltshire	Light brown	135·0	136·6	—	,,	79·0 c. of lime, 10·4 silica, 2·0 alumina, 3·7 c. of magnesia	Known as Tisbury, suitable for dressings and general building.
Clunch . . .	Cambridgeshire	White	133·0	72·0	—	Cretaceous	—	Fine grained, suitable for interior carving.
Doulting, fine .	Somersetshire	Cream	125·0	103·9	10·87	Jurassic	95·89 c. of lime, 2·04 silica	Fine grained, suitable for carving and interior work.
,, chelynch bed	,,	,,	150·0	211·6	3·36	,,	As above	Dressings and general building work.
Ham Hill, yellow bed	,,	Light brown	136·0	207·0	—	,,	52·0 c. of lime, 4·0 silica, 37·0 magnesia, 2·0 iron	General building work.
Ham Hill, grey bed	,,	Yellowish brown	146·0	259·0	—	,,	As above	As above.
Hopton Wood .	Derbyshire	Various colours	—	—	—	—	Fossil limestone	Takes a good polish, and used for interior work, panels, wall linings, and steps, etc.
Ketton . . .	Rutland	As above	156·7	—	—	,,	92·7 c. of lime, 4·1 c. of magnesia	Dressings and general building work. Sharp arrises cannot be worked on this stone.
Kentish Rag .	Kent	Blue-grey and greenish grey	166·6	—	—	Cretaceous	92·6 c. of lime, 6·5 alumina	Hard and compact, used for walling.
Purbeck freestone	Dorsetshire	Cream	150·0	—	—	Jurassic	—	Used for pavings and steps, hard and durable.
,, marble	,,	Grey and shelly, takes polish	—	—	—	,,	—	Shelly; is used for pavings, light shafts in Gothic church interiors.
Painswick . .	Gloucestershire	Cream	145·0	—	—	,,	—	Fine grained, suitable for interior work.
Portland— Base bed . .	Dorsetshire	Light cream	132·0	287·0	6·84	,,	95·16 c. of lime, 1·2 silica, 1·2 c. of magnesia	Fine grained regular, suitable for interior work generally.
Whitbed . .	,,	Light brown	132·3	204·7	7·5	,,	95·7 c. of lime, 3·1 silica	Probably the best limestone for exterior use in London. The stone varies in quality considerably.

None of the limestones are entirely satisfactory for exterior work, in London or smoky towns, and must be carefully selected, if used for this purpose.

DOLOMITES

Generally all these stones are of a highly crystalline nature, and are fine and regular, but need careful selection.

Name.	County.	Colour.	Weight in lbs. per cub. ft.	Crushing strain in tons per sq. ft.	Absorption. Per cent.	Geological series.	—	Remarks.
Anston	Yorkshire	Light cream	134·0	833·1	7·5	Permian	—	Good stone for exterior dressings, but needs careful selection. Was used in the Houses of Parliament and Geological Museum, London.
Bolsover Moor	Derbyshire	Yellowish brown	152·0	484·0		"	51·1 c. of lime, 40·2 c. of magnesia	Excellent for outside work. Was selected for Houses of Parliament.
Huddlestone	Yorkshire	Light cream	138·0	278·0	—	"	54·19 c. of lime, 41·3 c. of magnesia	Dressings and general building work.
Mansfield Woodhouse	Nottinghamshire	Warm yellow	145·0	577·0	—	"	74·32 c. of lime, 74·32 c. of magnesia	" " "
Roche Abbey	Yorkshire	Cream, speckled	139·0	250·0	—	"	57·5 c. of lime, 39·4 c. of magnesia	" " "

SANDSTONES

Name.	County.	Colour.	Weight in lbs. per cub. ft.	Crushing strain in tons per sq. ft.	Absorption. Per cent.	Geological series.	—	Remarks.
Aspatria	Cumberland	Dull red	125·0	759·7	8·50	Trias	Fine close grain	General building work.
Bramley Fall	Yorkshire	Light brown	162·3	552·2	3·70	Carboniferous	96·58 silica	General building and engineering work.
Caithness	Caithness-shire	Dark grey	157·0	—	—	Devonian	69·45 silica, 10·5 alumina and iron, 10·65 carbonate lime, 5·79 organic matters	Excellent for landings, steps, and flagstones, paving.
Closeburn	Dumfriesshire	Red	123·5	478·0	—	Trias	91·86 silica, 4·5 alumina	General building work, dressings, etc.
Corsehill	"	"	141·0	635·0	—	"	95·24 silica, 1·4 c. of lime, 1·23 c. of magnesia	As above.

Craigleith . .	Edinburgh	Very light grey	152·6	861·9	3·6	Carboniferous	96·95 silica, 2·30 alumina	General building work, steps, and landings.
Darley Dale . .	Derbyshire	Light brown	148·0	670·3	—	"	96·4 silica, 1·3 alumina	General building work and engineering.
Forest of Dean Grey . . .	Gloucester	Grey	149·0	569·0	—	"	80·16 silica, 14·4 alumina, 2·55 c. of lime	As above.
Blue . . .	"	Blue-grey	151·4	631·0	2·71	"	—	As above.
Blue . . .	Edinburgh	Light grey	149·0	459·7	4·7	"	92·23 silica, 2·93 alumina	As above.
Hailes, Pink .	"	Pale pink	142·5	511·3	5·3	"	96·7 silica, 0·84 alumina	As above.
" White .	"	Light drab	144·0	523·5	4·0	"	96·52 silica, 2·78 alumina	As above.
Howley Park .	Yorkshire	Light brown	140·3	466·7	4·9	"	—	General building work, dressings, etc.
Kenton . . .	Northumberland	"	142·5	—	—	"	—	As above.
Mansfield, Red .	Nottinghamshire	Red	143·2	591·9	4·58	Permian	49·4 silica, 3·2 alumina, 26·5 c. of lime, 16·1 c. of magnesia	As above.
" White	"	Cream	140·1	461·7	5·01	"	51·4 silica, 1·32 alumina, 26·5 c. of lime, 17·98 c. of magnesia	As above.
Park Spring . .	Yorkshire	Light brown	151·0	487·0	—	Carboniferous	—	General building work, steps, etc.
Bristol Pennant	Gloucester	Blue grey	172·0	1001	—	"	72·44 silica, 15·78 alumina, 2·03 c. of lime	As above.
Prudham . .	Northumberland	Brown	141·0	455·0	4·0	"	86·4 silica, 6·45 alumina	As above.
Rainhill . . .	Lancashire	Red	160·0	351·0	—	Trias	—	General building; this stone is being used for internal walls of Liverpool Cathedral.
Robinhood . .	Yorkshire	Blue-grey	144·6	574·0	3·9	Carboniferous	—	General building, steps, dressings, etc.
St. Bees . . .	Cumberland	Red	134·6	506·9	—	Trias	85·2 silica, 7·0 alumina	General building work, dressings, etc.
Shamrock . .	Co. Clare, Ireland	Dark grey	167·0	1902	—	Carboniferous	84·9 silica, 6·6 alumina	Hard and compact, excellent for landings, paving, etc.
Wealden . . .	Sussex	Light yellow, brown streaks	150·0	279·2	10·34	Cretaceous	—	Soft, fine-grained stone, unsuitable for outside work in London.
Wilderness . .	Gloucester	Dull red	141·0	695·0	—	Devonian	88·7 silica, 3·25 alumina, 2·9 c. of lime	Steps, landings, pavings, etc., and general building.
Woolton . . .	Lancashire	Dull red	160·0	400·0	—	Trias	—	General building and dressings.

Limes and Cements

Limes are produced by burning or calcining chalk or limestone. They are usually classified under three heads—

1. Rich, pure or fat limes.
2. Poor limes.
3. Hydraulic limes.

Lime is known as rich when it is calcined from nearly pure carbonate of lime.

Poor lime contains a quantity of insoluble impurities, such as sand, which has no chemical action upon the lime. These limes are of little use to masons.

Hydraulic lime contains a more or less quantity of clay and other useful impurities, which, when calcined, combine with the lime and confer the power of hydraulicity; that is, the power of setting under water.

The hydraulicity of the lime depends upon the amount of useful foreign impurities it contains. It is said to be feebly hydraulic when containing about 10 per cent. of clay, moderately or ordinarily hydraulic when containing about 20 per cent. of clay, and eminently hydraulic when containing over 20 per cent. of clay.

Grey chalk lime or stone lime is of a feebly hydraulic character. It is obtained from the south of England, and is known as **Halling, Dorking,** etc., the districts from which it is obtained.

Lias lime is moderately or eminently hydraulic, according to the district from which it is procured. It is obtained chiefly from Leicestershire, Somersetshire, Lyme Regis in Dorsetshire, Yorkshire, and Warwickshire. Good hydraulic limestones are also found in Scotland and the north of England. Hydraulic lime is also produced artificially, by mixing lime and clay in correct proportions.

Selenitic lime or selenitic cement, is made by adding a small proportion of gypsum (plaster of Paris) to hydraulic lime, the plaster of Paris being perfectly mixed and ground with the lime. Selenitic lime sets more rapidly than lime, does not slake, and may be used with a larger proportion of sand.

Plaster of Paris is made by calcining gypsum (sulphate of lime).

Roman cement is a natural cement, and is produced by burning small lumps or nodules found in the London clay. It

is brown in colour and weighs 75 lbs. per strike bushel. It sets very rapidly, and should be kept in casks in a dry state, as it becomes inert if exposed to the air. It is not strong, and is now almost entirely superseded by Portland cement.

Portland cement is manufactured from chalk or limestone and clay. There are three processes of manufacture, known as the wet, semi-wet, and the dry. In the Thames and Medway districts the wet process is used.

Chalk and river mud (clay) in definite proportions is thoroughly mixed, washed, and strained in a mill, the resultant mixture, known as slurry, is tested, and more or less carbonate of lime (chalk) added, to produce the exact chemical combination.

The slurry is then conveyed to a large tank, where it is allowed to settle for six to twelve weeks whilst the water is drawn off. It is then burned in a kiln. Rotary kilns, which are now largely used, consist of a long cylindrical iron chamber 60 to 120 feet long by 6 or 8 feet diameter, inclined to the horizontal and lined with firebrick.

The slurry is fed into the kiln from the upper end, whilst a powerful blast of fire is introduced at the lower end, causing a white heat.

The kiln is kept rotating by electric motors, and the slurry gradually passes along until it drops out at the lower end in the form of clinker. The clinker passes through a revolving cooling drum, and is then passed on to the grinding mills, where it is ground to a fine powder.

The dry process differs somewhat from the wet process, and many different kilns and grinding machines are used by different makers.

Good cement should be grey or greenish grey in colour, and should weigh about 110 lbs. per strike bushel.

Fineness.—The finer the cement is ground the greater the bulk and the less it will weigh. It is now generally recognized that finely ground cement is better than coarse, and the improvement in machinery has enabled manufacturers to produce cement of the fineness of flour. The weight should therefore be judged in comparison with its fineness.

The British standard specification states that 4 ozs. of cement, after being continuously sifted in a sieve having 5,776 meshes per square inch, shall leave a residue not exceeding 3 per cent., and that the residue on a sieve 32,400 meshes per square inch shall not exceed 18 per cent.

Tensile Strength—Neat-test.—Cement is tested for its tensile strength, by being carefully made into briquettes with just sufficient water to make a satisfactory paste. The briquettes are laid in water for a period of seven days, and are then placed in a machine, and the weight is gradually applied until the briquette breaks.

The narrowest part of the briquette is of one inch square section, and after seven days from gauging should stand a tensile stress of 400 lbs. per square inch. Twenty-eight days from gauging the stress should be 500 lbs. per square inch.

This test must be carefully executed, especially in the making of the cement paste and in the moulding of the briquette.

Setting Time.—Cement is said to be "set" when an instrument (Vicat needle) weighing $2\frac{1}{2}$ lbs. and having a flat end $\frac{1}{16}$ inch square fails to leave an impression when placed gently on the surface. Quick cement sets in from 10 to 30 minutes; medium cement in from half an hour to two hours; slow cement in from two to seven hours.

Soundness.—Cement is tested for expansion by the Le Chatelier instrument. Good practical tests may be made requiring very little in the way of instruments.

Two pats of cement should be made three to four inches in diameter and a quarter of an inch thick, and placed on a polished glass surface. One should be placed under water when set, and the other left in a cool room away from the sun and free from draught. These pats should be regularly examined for a period of fourteen days. The best Portland cement should show no signs of cracking, scaling, or warping.

The cement may also be tested by filling a bottle or test-tube with cement in the form of thick grout and placing it in a cool place. Should the cement be of poor quality, or if it is too fresh, it will expand and crack the glass. If it has too much clay it will contract and become loose.

Storage.—Portland is usually supplied in bags, eleven bags to the ton. It should be spread out on a wood floor and turned occasionally, so that every particle may be thoroughly air-slaked.

CHAPTER VII

STEREOTOMY

STEREOTOMY is the art of cutting solids into sections of suitable size and shape, and involves a knowledge of practical geometry that is seldom possessed by the average mason.

Young masons who hope to become setters-out should study the science under the guidance of a practical teacher.

The series of examples given in the following pages illustrate many interesting applications of geometry to practical work, and it is hoped that they will prove of value to the geometer. The information is presented in as simple a manner as possible, and the craftsman should be able to follow the methods without difficulty.

There are three distinct problems requiring solution—

1. To decide the best form, arrangement, and position of beds and joints, to ensure stability.

2. To determine the templates or moulds that will enable the mason to accurately shape the stone to the prearranged design.

3. To apply the moulds and work the stones to the correct form in accordance with the drawings.

In determining the form and arrangement of the joints, regard must be paid to the cardinal principles of masonry.

(*a*) Bed joints should be placed as nearly as possible at right angles to the axis of pressure, in order to minimize the tendency to slide. Bed joints should be truly worked to ensure a uniform stress over the whole area.

Where bed joints are not at right angles to the face, and the load is considerable, they should be formed as in Fig. 260, to avoid acute angles.

Stones are liable to spall if the bearing surface makes an acute angle with the face.

The practice of working beds hollow cannot be too strongly

condemned. The pressure is not evenly distributed over the bed of the stone, and in consequence the face of the stone spalls (see Fig. 261).

(*b*) Heading joints should be normal to the face of the work, and should be accurately shaped to fit adjacent stones.

(*c*) All sandstones and limestones are more or less stratified, and will in general sustain a greater load when the planes of stratification are at right angles to the axis of pressure.

They also offer the greatest resistance to the weather when in this position.

All sedimentary rocks should therefore be **placed on their natural bed,** and in the case of arch stones, *i.e.* **voussoirs,** the centre line of the voussoir should be parallel to the planes of bedding (see Fig. 264).

NOTE.—Complex structures would often require joints of exceptionally difficult shape, and the mould-cutter would be well advised to use, as far as is possible, joints of a simple nature, in preference to the occasionally more exact geometrical surface that would strictly comply with the foregoing conditions.

In the following examples many terms are used that may require explanation.

Surface of Operation or **Operation Plane.**—A plane surface must first be worked on every stone, and this surface may be a **bed, joint, face, back,** or some other **plane surface** tangent at some particular point with the finished stone.

The surface may be partly or entirely cut away by subsequent operations; but the plane from which the mason applies the **mould, squares,** or **gauges** preparatory to further work, is known as the **surface or plane of operation.**

Beds.—In walls the beds are the horizontal joints upon which the stone rests. The upper surface is known as **the top bed,** the lower surface the **bottom bed.**

The beds of voussoirs in arches are the surfaces practically normal to the axis of pressure, but have generally been referred to as **bed joints** in the following examples to distinguish them from horizontal beds.

The beds in domes are usually conical and are placed as nearly normal with the axis of pressure as is possible. **Beds** may therefore be considered as surfaces receiving and transmitting pressure.

Joints.—Joints are surfaces that abut another stone, but do not in general receive pressure.

Face.—The face of a stone is the exposed surface.

Back.—The back of a stone is the side or surface opposite to the face and is usually hidden in the wall (see Figs. 268, 269).

In setting out masonry work to full size for the purpose of cutting moulds, it is not necessary to draw the whole of any symmetrical example.

In the case of arches, which are mostly symmetrical about a

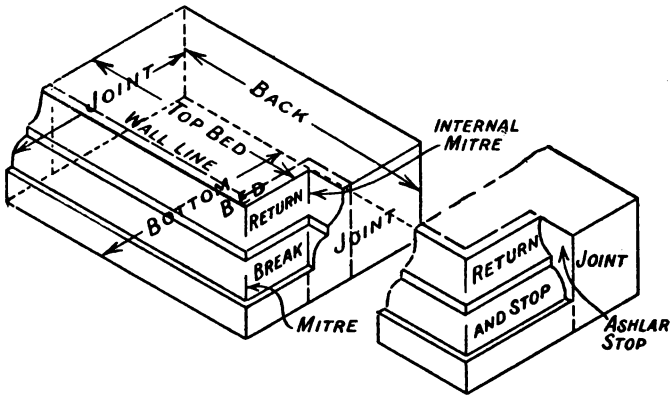


FIG. 268. FIG. 269.

centre line, it is only necessary to draw rather more than one-half so as to include the keystone.

EXAMPLE.—Fig. 270 is an example of a moulded semi-arch, with its voussoirs blocked out to meet the courses of ashlar.

XY is the springing line, and ON is drawn at right angles to represent the centre line. AO is half the span, and the section of the moulding is shown in Fig. 271.

With O as centre and OA as radius, describe rather more than half the soffit AD.

From the plan (Fig. 271) project a, b, c to the springing line, and describe arcs representing the arrises of the moulding in elevation.

The dotted line d_1d_2 represents the check at the back of the arch to receive the door or window frame.

Divide the quadrant AD into the number of stones that are required in the arch. This must be done by the dividers, trial, and error, and adjusted until the arc divides into the desired number as at 1, 2, 3, 4, etc.

From centre O, draw lines through the odd numbers to represent the bed joints, as at 1, 3, 5, etc., making 1D equal D'*n* at the keystone.

The first course of ashlar above the springing line is 15 inches deep, and the other courses are 12 inches.

The drawing can thus be completed.

To cut the Moulds.—Cut a piece of zinc with one straight edge, rather larger than the voussoir in elevation. Tack the zinc to your drawing, allowing the thickness of the joint at the **bottom** of the voussoir. Scribe all the straight lines on the zinc as shown in Fig. 270, and trim the zinc to these lines. Cut the moulds for each voussoir in a similar manner, and refix them to the board in their correct position, allowing the space between each for the bed joint. The circular lines *a*, *b*, *c*, A may then be scribed on the zinc with the trammel, and the waste zinc cut off at the soffit line.

The zinc moulds should be numbered as at I, II, III, etc., and are known as **face moulds**. If one arch only is required to the drawing, two stones would be wanted to each mould, except the keystone, and the moulds should be marked—

No. 1 **to this lines up.**

No. 1 **to this lines down.**

or No. 2 to this **handed.**

If more than one arch is required, the moulds must be marked in accordance.

Only one **bed joint mould** is required, the lines *k*, *l*, *m*, etc., being scribed on the mould to represent the extremity of each bed joint.

Convex reverses, as at RST, made of wood or stout zinc, are desirable, and give the mason considerable assistance in execution of accurate work.

Reverse mouldings are sometimes useful, but care should be taken to see that they are applied normal to the curvature, as shown dotted by lines in Fig. 273.

Many schemes are adopted in transferring the contour of the moulding from the drawing to the zinc, and the following may be found useful.

The architect usually supplies a full-size moulding on thin detail paper, and if a piece of zinc is acided (hydrochloric acid) on one side it may be written upon with pencil.

Place this piece of prepared zinc under the full-size drawing with a sheet of carbon paper between the drawing and the zinc, draw over the lines of the detail with a hard pencil or tracer,

and the carbon paper will transfer the lines to the prepared surface of the zinc.

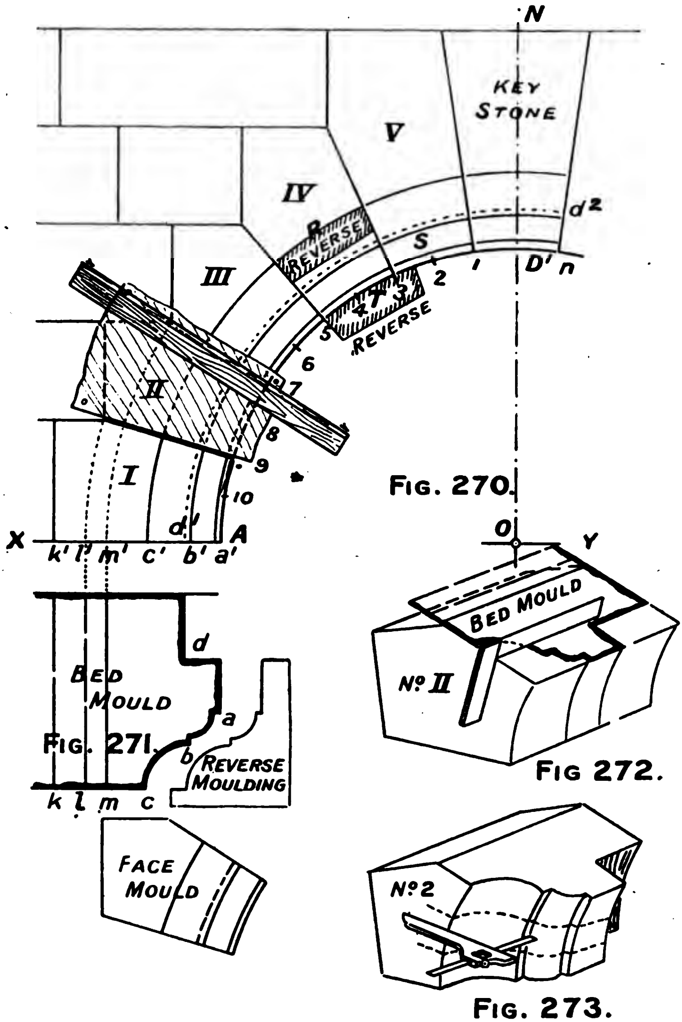


FIG. 270.

FIG. 271.

FIG 272.

FIG. 273.

Cut as closely and as evenly to the lines as possible, any little irregularities being filed off with a smooth file.

Moulded Ellipse Arch with Panelled Soffit

Figs. 274 to 276 illustrate an example of an ellipse arch with moulded face and moulded panel soffit.

In the example one half of the arch is shown in elevation, and the other in section. In actual practice it would only be necessary to draw half that shown in elevation, the section of the panel moulding being drawn on the same side. They have been kept separate for clearness.

Draw the springing line horizontal and the centre line at right angles. From O mark off half the span as at A and the rise as at D.

Describe the soffit by one of the methods previously described, preferably the trammel shown in Figs. 152 and 153.

Gauge the lines I, II, III, IV parallel to the ellipse to represent the arrises of the moulding, and arrange the bed-joints to avoid cutting the panel moulding longitudinally.

Develop half the ellipse soffit by pricking over with a pair of dividers and transferring to a straight line as at XX (Fig. 275), and draw the panels and joints on this development.

The face moulds, bed-joint mould, or section, and the soffit moulds for Nos. 1 and 3 stones may then be cut, the intersection of the lines on the soffit moulding being pierced through the zinc as at *r*, *s*, *t*, *u*, etc.

The section or bed-joint mould should have holes pierced to indicate the joggle.

Several reverses should be cut to assist the mason to accurately work the stones.

The face moulds should be cut as described in previous example, and the thickness of the joints should be allowed from the face and soffit moulds.

To Work No. 3 Voussoir.—Work the face as a plane surface, and although this is nearly all cut away in subsequent operations, it is the **surface of operation,** and if not accurate subsequent operations must be inaccurate.

Next apply the face mould *a*, *b*, *c*, *d* **lines up,** and work the bed joints square with the face. Apply the section mould to a line square with the face, either the soffit line *ea*, or the extrados line *bf* (Fig. 277).

Apply the face mould to the back of the stone **lines down,** and scribe the intrados and extrados.

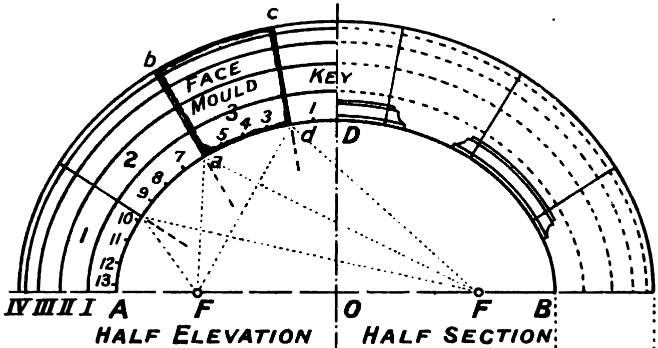


FIG. 274.

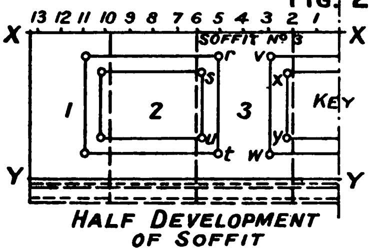


FIG. 275.

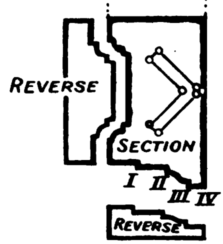
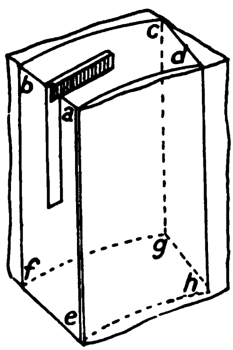
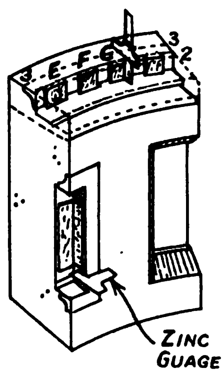


FIG. 276.





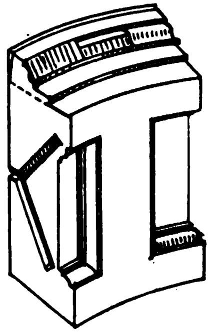


FIG. 277. FIG. 278. FIG. 279.

Work the extrados, testing with a straight-edge from front to back.

It is only necessary to work cleanly, that portion of the soffit that will not be cut away in the panelling.

Apply the soffit mould, and work the panel with the aid of the sinking square and zinc gauges (Fig. 278).

Lastly, work the face moulding, using the trammel (Fig. 16) to scribe the lines 1, 2, 3, 4, and sinking small drafts E, F, G with the aid of the sinking square (Fig. 278).

Reverses to fit the two fillets would be an aid to accuracy, and the cyma reversa may be worked by chamfer and check, as illustrated in Fig. 279, which shows the stone in a nearly completed condition.

Arches of Double Curvature

Circle on circle is a term often used by masons to define intricate circular work, and arches circular on plan are frequently referred to by this term.

Two examples are given in the following pages, but there are a large number of examples that are outside the scope of this small book.

Both examples are frequently used in modern practice, and have been chosen so as to demonstrate two distinct methods of construction.

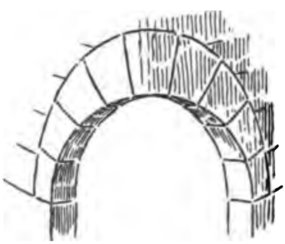


Fig. 279a.

Fig. 280 illustrates an arch in a cylindrical wall, the soffit being generated by a moving horizontal line, one end of which is directed by a fixed vertical line, whilst the other end is directed by a semicircle on the cylindrical wall.

This curved director may be an ellipse, a parabola, or any other curve; but a semicircle has been chosen for illustration.

This form of arch is suitable for walls having pronounced curvature, but it is sometimes necessary to rectify the extrados to avoid the appearance shown in Fig. 279a.

Figs. 286, 287 illustrate an arch the soffit of which is the portion of a cylinder. This form of arch is more suitable for walls having a flat curvature. It possesses many advantages.

Firstly, the beds are plane and not twisted surfaces.

Secondly, the arch may first be worked as an ordinary arch and the superfluous stone worked off the face and back to the wall lines.

Thirdly, there is no difficulty in applying mouldings to the plane beds, although the moulding would vary from springing to crown.

The example that is given is shown in a wall of sharp curvature, simply to illustrate the zig-zag joint adjacent to the ashlar. In walls of flat curvature this zig-zag joint would not be necessary.

Arch in Cylindrical Wall

Fig. 280 illustrates an arch in a cylindrical wall, all straight lines lying on the soffit being normal to the wall surface. **The soffit is therefore conoidal and undevelopable.**

Commence by drawing the centre line NZN′, and with O1 as centre, O1N and O1Z as radii, describe the arcs forming the plan of the outer and inner wall surfaces.

Plot the plan of the opening on the face as at 7N7, and draw lines converging to the centre C1 to represent the plan of the abutments. Measure the circular arc N7 and set it upon the springing line XY, as at O7 in development.

This development may now be treated in the same manner as an arch in a straight wall. In the example it is the quadrant of a circle described from centre O, with O7′ as radius.

With O as centre, O14′ as radius, describe the extrados.

Draw the joints converging to the centre as before described for arch in straight wall.

Draw vertical projectors from 1′, 2′, A′, etc., on the soffit to the springing line XY, and from 8′, 9′, B′, 11′, etc., on the extrados to the stretch-out line *xy*, as at L14. Mark these points on a lath that will bend, and transfer them to the convex face of the wall in plan. The example shows the soffit points on the left-hand side of the centre line, and the extrados points on the right-hand side of the centre line in plan.

From these points draw lines converging to the centre O1 until they intersect the concave wall surface. Mark the points from the concave surface on a bender and transfer them to the inside development.

Z to 7 on the left-hand side of plan is transferred to XY, inside development, whilst N14 is transferred to *xy* to avoid confusion.

Draw vertical projectors from these points, and draw hori-

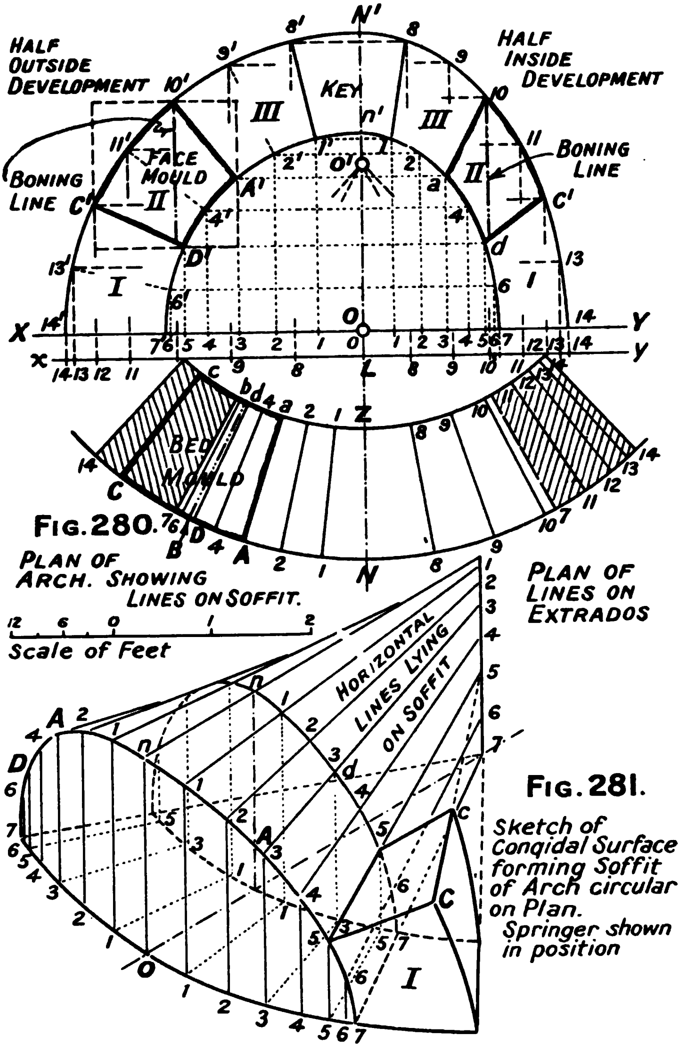


FIG. 280. PLAN OF ARCH. SHOWING LINES ON SOFFIT.

FIG. 281. Sketch of Conoidal Surface forming Soffit of Arch circular on Plan. Springer shown in position

zontal ordinates from the points on the outside development. The intersection of the vertical projectors and the horizontal

ordinates being points in the inside development, fair lines may be drawn through them to represent the intrados and extrados.

The joints on the inside or concave face converge to the centre O, and if the arch is correctly drawn will intersect in corresponding points on both intrados and extrados.

Reference to Fig. 281 will make clear to the beginner the peculiar conoidal surface, part of which is actually the soffit of the arch. It will also make clear the reason for obtaining developments of the convex and concave surfaces, the projectors in the diagram being numbered to correspond with the numbers and letters in Fig. 280.

The joints if worked to the moulds would be **helocoidal,** but as a straight-edge is used to test the drafts across the chord on both inside and outside, they become ruled surfaces, sufficiently near to the **helocoid** for all practical purposes.

To Work the Voussoirs

Voussoir No. 2.—The inside and outside face moulds are indicated in Fig. 280, the bed mould in plan.

The dimensions of the stone required to contain this voussoir is $1' \, 5'' \times 1' \, 4\frac{1}{2}'' \times 1' \, 5\frac{3}{4}''$.

First prepare the surface of operation and apply the bed mould, scribing the lines on the stone as shown in Fig. 282.

Work the concave and convex, inner and outer surfaces, and draw the boning line on these faces square with the surface of operation, testing them for accuracy by boning, as described in chapter on conversion of stone.

Apply the face moulds to these boning lines, taking care to keep the points B*b* just touching the operation plane. Work the top bed joint by making a draft from A to *a*, and scribing the line at the intersection of the bed joint and soffit.

Work drafts from A to B and *a* to *b* along the scribed edges of the face moulds, and complete the joint by working across from these drafts.

Care must be taken that the drafts are truly worked, and that the straight-edge is applied from A to *a*, T to *t*, R to *r*, etc., which are level lines lying on the surface of the bed joint (see Fig. 284).

The bottom joint is worked in the same manner.

The extrados and soffit should be worked by means of a

series of drafts taken from the front to the back, as shown in Fig. 284.

Fig. 285 shows the stone in a finished condition.

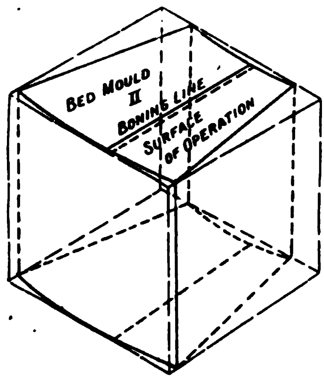


FIG. 282.

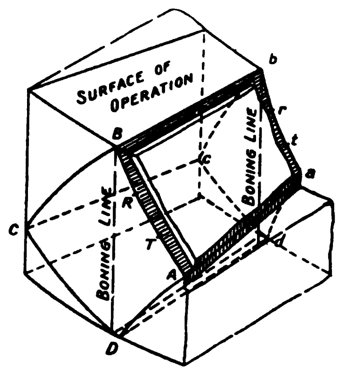


FIG 283.

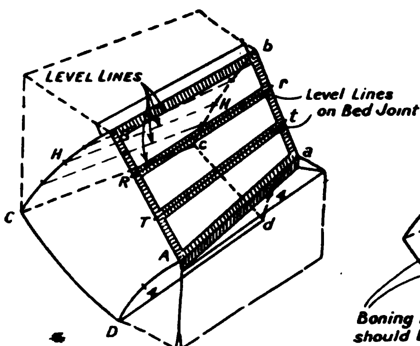


FIG 284

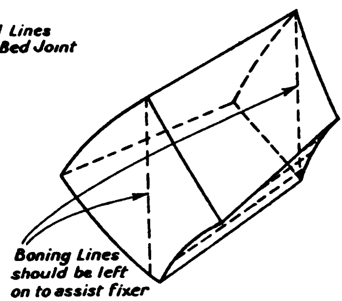


FIG 285.

ARCH IN CYLINDRICAL WALL WITH DEVELOPABLE SOFFIT

In this example the axis of the cylinder forming the wall surface intersects the axis of the soffit cylinder at right angles.

It should be noted that the soffit makes a very acute angle with the external face of the wall at the abutment (see Fig. 287), the fault being more pronounced where the extrados joins the

internal wall surface. The ashlar abutting the voussoirs would also have very unsatisfactory joints (see Fig. 287), and the joints have therefore been made normal to the wall surface for a distance of four inches, causing the zig-zag joint shown in the plan.

For this reason these arches are more suitable for walls of flat curvature, but the acute angle at the soffit and the external wall may be minimized by a good moulding.

To Set Out the Arch

Commence by drawing the centre line NOM and the springing line XY (Fig. 286).

With O as centre describe a semi-arch and draw the joints as for an arch in a plane wall, the dotted line representing the extrados.

Block out the voussoirs to bond with the ashlar courses, as shown on the internal elevation.

With O1 as centre, describe the circular arcs forming the plan of the wall, and project the beds on the soffit from the elevation to the plan.

It must be specially noticed that in this example the **elevation** and not the **development** of the arch is drawn, and the voussoirs would first be worked from the face moulds as for an arch in a plane wall.

To Cut the Moulds for No. II Stone

The mould for the internal face is bounded by the points *a′*, *b′*, *c′*, *d′*, *e′*, and these points correspond to the points *a′*, B′, C′, D′, *e′* on the external elevation.

Project them to the plan, and from *ae* draw the joint *aer* normal to the concave face. From *r* draw a line parallel to the centre line until it cuts the external face at FA; and draw the normal joint FA*t*; join *rt*, and *ab*BA*tr* is the required **bed mould.**

Project FA to the elevation, and ABCDEF is the **face mould.**

The **bed-joint moulds** are shown on a separate plan; but this plan (Fig. 288) is in every respect similar to the plan at Fig. 287, O2 being the centre from which the wall curves are described.

Take any number of points on the elevation of the bed joint $c'b'$; one only u' is taken in the example.

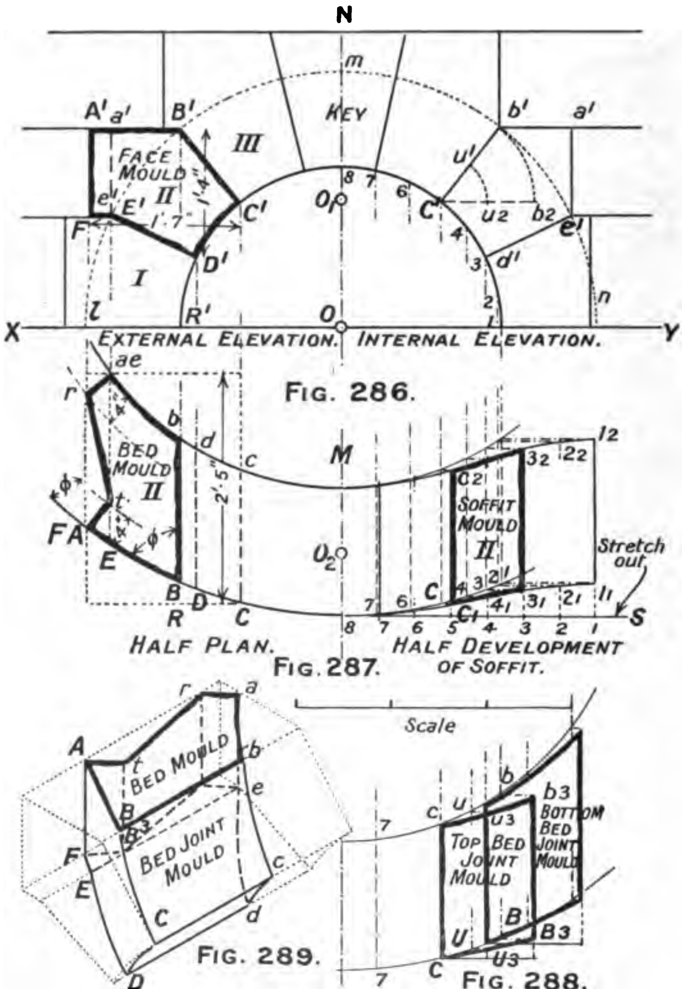


FIG. 286.

FIG. 287.

FIG. 289.

FIG. 288.

SKETCH OF No. II.

PLAN FOR JOINTS.

With c' as centre, describe arcs from u' and b', until they intersect a horizontal line from c', as at $u2$ $b2$ (Fig. 286).

Project *c'u'b'* to the plan (Fig. 288), as at CUB, *cub*, and from these points draw ordinates at right angles to the centre line.

Project *u*2, *b*2 to the plan until they intersect the horizontal ordinates U3B3 on the convex face, and *u*3 *b*3 on the concave face, which are points in the true shape of the bed-joint mould. C, U3, B3, *b*3, *u*3, *c* is the top bed joint mould for No. II stone. The curves are portions of ellipses, and more points should be taken to ensure accuracy. The bottom bed joint is found in a similar manner.

A **soffit mould** is required, and the soffit of the arch must be developed to obtain this mould.

Take any number of points on the soffit of the arch as at 1, 2, 3, 4, *c*, etc. (Fig. 286). Project them to the plan 287, drawing the generators as represented by the dotted lines.

Draw a line at right angles to the centre line, as at 8S (Fig. 287), and set out the chords of the soffit as at 8, 7, 6, 5, 4, 3, 2, 1.

Draw vertical ordinates from these points, and horizontal ordinates from the intersection of the generators, and the convex wall face will intersect at 1_1, 2_1, 3_1, 4_1, c_1, etc., through which a fair line is drawn.

The development of the concave surface is found in a similar manner, and C_1, C_2, 3_2, 3_1 is the **soffit mould** of No. II stone.

To Work No. II Voussoir (Fig. 289)

Stone required 1′ 7″ × 2′ 5″ × 1′ 4″.

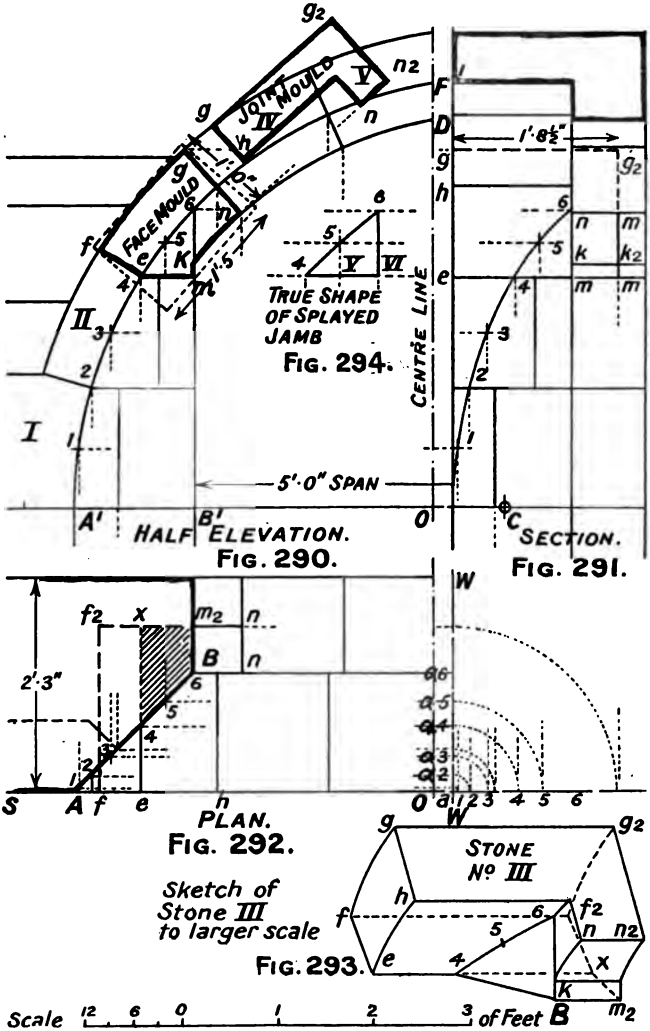
Work the top bed, and square the back and front sufficient to apply the face mould. Work the beds and soffit, as for an arch in a plane wall, represented by the dotted lines in sketch.

Apply the **bed mould** with the point *a*, touching the back of the stone. The **top bed joint mould** should next be applied, so that the point B3 coincides with the point B on the horizontal bed. The **soffit mould** is next applied, C1 coinciding with C and *c*2 coinciding with *c*. The **bottom bed joint mould** is then applied, and the superfluous stone is worked off, the chisel drafts being at **right angles** to the horizontal bed. The joint adjacent to the ashlar may be squared from the top horizontal bed.

The Rere Arch

The rere arch was much used in Gothic architecture, and affords an interesting example of stereotomy.

The example illustrated in Figs. 290 to 292 has fewer joints



HALF ELEVATION. FIG. 290.

SECTION. FIG. 291.

PLAN. FIG. 292.

FIG. 293.

FIG. 294.

than those used in mediæval buildings to more clearly illustrate the work.

The arches were used in thick walls, where the jambs of the window openings were splayed inside to admit and diffuse as much light as possible over the interior. The soffit of the arch had little or no splay, so that the light was diffused downwards.

This arrangement gives a peculiar intersection where the soffit of the arch meets the splayed jambs (see Fig. 291).

Commence by drawing the plan (Fig. 292), and from this project ABO to the springing line, and set up the elevation. C is the centre from which the arch is described, and CA′ the radius.

The voussoirs are pricked over on the soffit line A′F′, and the joints are drawn converging to the centre C.

No. 6 is the highest point at which the splayed jamb meets the soffit (Fig. 290), and a series of points, as at 1, 2, 3, 4, 5, are taken on the soffit A′F′ to enable the draughtsman to plot points on the section. Project these points from the elevation to the splayed jamb in plan, as at 1, 2, 3, 4, 5, 6, and from there project them horizontally to WW, a vertical line coinciding with the face of the wall in section. With *a* as centre and *a*2, *a*3, *a*4, etc., as radii, describe arcs of circles to horizontal line ST, as at 1, 2, 3, 4, 5, 6. Draw projectors from these points up to the section, and from the elevation project the points of the same numbers, until they intersect at 1, 2, 3, 4, 5, 6 in section. A fair line passing through these points represents the intersection of the soffit and splayed jamb in section.

To Work Voussoir No. III (Fig. 293)

Moulds required: **Face mould,** *m, e, f, g, n*; **joint mould** *g, g*2, *n*2, *n, h*; **bed mould,** *x, m*2, B, 4, shown hatched in plan.

Stone required, 1′ 5″ × 1′ 8½″ × 1′ 0″.

Work the face and apply the face mould, work the top and bottom bed joints, work the back joint, and apply the face mould on the back joint lines down.

Work the horizontal bed and apply the bed mould. Apply the joint mould to the top joint.

Work the extrados by chisel drafting from front to back. Work the soffit and the small portion of the upright jamb, square from the back joint.

The soffit line *e h* on face is trammelled from the extrados, or preferably from a zinc mould contained by the points *h, e, f, g*.

The soffit of the second order may then be worked with the aid of a sinking square from the face, and a reverse template.

The splayed jamb B, 4, 6 may be worked with the aid of a sinking square from the level bed. Care must be taken when working the intersection of the soffit and splayed jamb 4, 5, 6, and a zinc mould of the true shape of this small triangular piece would aid the mason in obtaining a good line (see Fig. 294).

This is found by drawing projectors from the section or elevation, and measuring 4, V, VI from 4, 5, 6, along the splayed jamb in plan, the projectors intersecting at points in the curve at 4, 5, 6 (Fig. 294).

Fig. 293 is a sketch of the **voussoir** completed.

Mouldings Interpenetrating Chamfer Jambs (Fig. 295)

An interesting example of stereotomy, something similar to the rere arch, and associated with Gothic work, is that of mouldings dying into, or penetrating, a plane jamb.

In the example only the first two voussoirs are shown, so that the mouldings are drawn to as large a scale as possible.

BA is the plan of the chamfer jamb, DB the face of the wall; XY is the springing line, and C the centre from which the arch is described.

Describe the arch and the plan of the jamb in the usual manner; design the moulding that is to be worked on the arch, so that it lies within the chamfer.

The elevation of the lines of interpenetration are found as follows:—

Points in the casement, or large hollow, are numbered 2, 3, 4, 5, 6, 7, as shown in plan. Project these points parallel to the face of the wall to the chamfer line, as at II, III, IV, V, VI; the point VII coincides with V.

Project points 1, 2, 3, 4, 5, 6, 7 to the XY, and from C describe arcs of circles, as shown by dotted lines in elevation.

Project the points I, II, III, IV, V, VI to the elevation, and where they cut the arcs of circles with corresponding numbers, are points in the line of interpenetration.

The interpenetration of the other mouldings are found in the same manner.

To find the top bed mould of the springer, see Fig. 296. This has been shown on a separate plan, but could be drawn on the original plan in actual setting out.

It is required to find the line of the chamfer; the arch moulding will remain the same.

Extend the chamfer line BA (Fig. 296). Project F′ in

elevation to *f* on the extended chamfer line, project *f* parallel to the face of the wall to F.

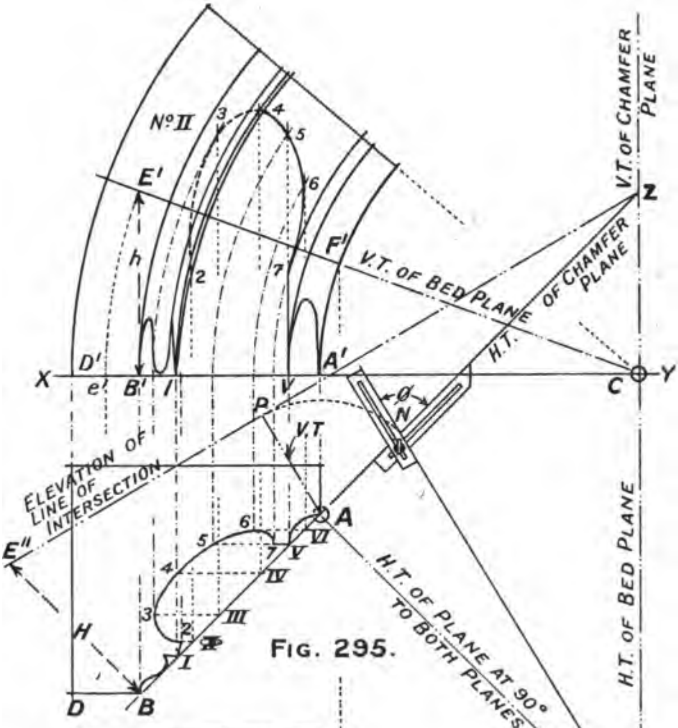


FIG. 295.

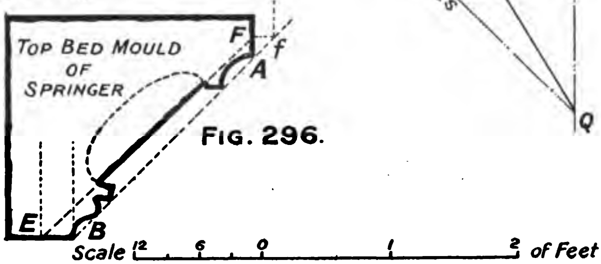


FIG. 296.

With centre C, radius CE′, describe arc of circle to *e*′, project *e*′ to E in plan, draw a line from F to E, the position of the chamfer at the top bed of the springer. The moulding shown

in dotted lines would be inside the chamfer line, and would not appear on the springer.

For correctly working the second stone it is necessary to know the angle between the bed and the chamfer jamb.

The bed line is continued to C, and is known as the vertical trace of the bed plane. As it is an inclined plane, its horizontal trace is at right angles to the XY.

The chamfer jamb is a vertical plane, and the chamfer line is continued until it intersects the HT of the bed plane at Z.

The elevation of the intersection of the two planes is found by measuring the height of E′ above XY and making BE″ equal to B′ E′. From P draw a line at 90° to the line of intersection, as at PA, and from A a line at 90° to the chamfer jamb until it intersects the HT of the bed plane at Q. These lines are the VT and HT of a plane at right angles to both the chamfer and bed planes. From A with AP as radius, describe arc of circle until it intersects the HT of chamfer plane at N.

The angle between the bed and the chamfer jamb in No. II voussoir is ϕ.

When working the stone, care must be taken to apply the shiftstock in such a manner that the blades are at right angles to the arris.

Pediment in Straight Wall (Figs. 297 to 300)

As this pediment is symmetrical, it is only necessary to set out rather more than half, so as to contain the **apex** or **saddle** stone. Very little description is necessary. Draw the centre line and the bottom bed line at right angles to it, set out the position of the truss, and from the architect's full-size detail, transfer the return moulding to your setting out, as at EF. From B set up the height of the pediment as at D, and join ED; from 1 and 2 draw lines parallel to ED, and from 2, 3, 4, 5, 6 draw horizontal lines to represent the arrises of the mouldings.

Make the fillet immediately beneath the cyma recta *the same width as the horizontal nose.* The rest of the raking moulding is exactly the same as the horizontal moulding, and 4, 5, 6, 7 is measured from the horizontal moulding.

Plot the return moulding on the right-hand side of the truss, and make the vertical joint of the springer just touching the return nose, as at JK.

This vertical joint may be carried to the bottom raking bed

of the moulding, and squared across the moulding, or the joint may be made as in the example, MK being square with ED.

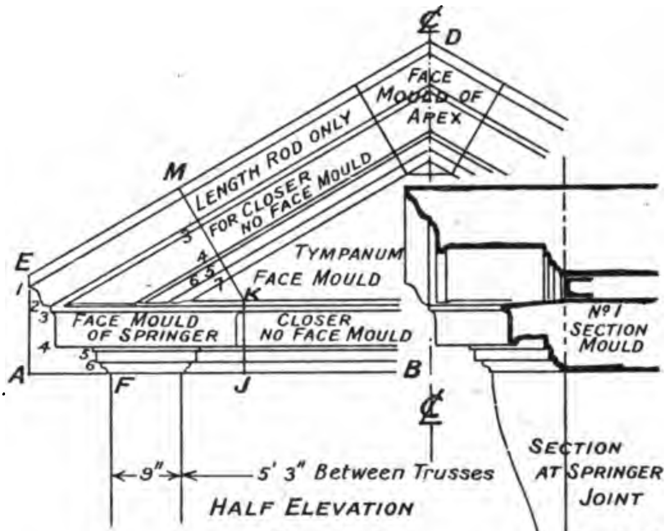


FIG. 297. FIG. 298.

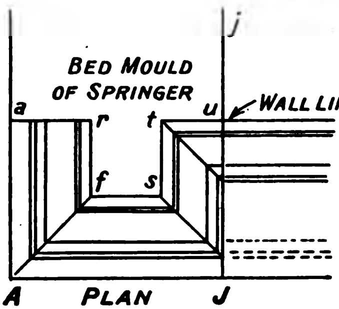


FIG. 299.

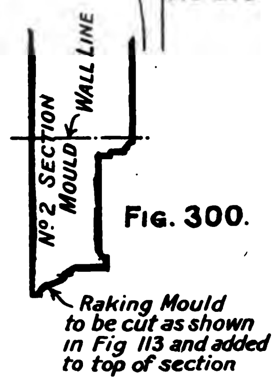


FIG. 300.

It is necessary to have a bed mould for this springer, owing to the break of the moulding round the truss, and the points

a, r, f, s, t, u (Fig. 299) should be stabbed into the zinc, so that the mason may scribe the points on the stone.

A section of the horizontal moulding is required, care being taken to allow a good weathering on the top, so as to turn off the water (see **No. 1 section mould,** Fig. 298). The same moulding, but with an enlarged throat, and with the **raking ogee** added to the top, is required for the raking joint MK.

(Fig. 113 and text in an earlier chapter describes the method of finding the raking mould.)

Face mould and **section** No. 2 is required for working the apex stone.

A face mould is necessary for the triangular piece of ashlar known as the **tympanum.** It is better to give a complete mould of this, and not a half only; the extra zinc that is used is economical, especially as the zinc may be used over again.

The raking and hoiizontal **closers** only need a rod for the length. The section or joint moulds being supplied in the ordinary way.

(*The working of a pediment springer is explained in an earlier chapter.*)

Niches.—Niches are recesses built into walls for architectural purposes. They are often arranged to receive statues. In Gothic work, the body of the niche is mostly polygonal, with an elaborate canopy or hood enriched with moulded ribs and carved bosses. In classic work, the body of the niche is usually cylindrical in form, the hood being either **spherical, spheroidal, ellipsoidal,** or a surface formed by the revolution of some curve.

When the hood is **spherical,** both the plan curve and the curve in elevation are circular arcs.

The hood is **oblate spheroidal** when the plan curve is a semi-ellipse, and the curve in elevation is a semicircle; or *vice versâ*.

The hood is **prolate spheroidal** when the curves in both plan and elevation are semi-ellipses, having both major and minor axes of the same dimensions.

If the ellipse in plan is different to the ellipse in elevation, then the hood is said to be **ellipsoidal.**

The body of the niche seldom presents trouble to the setter-out or mason; but the hood offers an interesting example to the student.

The jointing of the hood depends upon its surface. If the

hood is spherical, the beds and joints may be placed as shown in either of the examples.

If the face curve is a semicircle, and the plan curve a semi-ellipse, it is preferable to joint the hood as shown in Fig. 301.

If the face curve is a semi-ellipse and the plan curve a circle, it is advisable to place the joints as Fig. 304.

In Fig. 301 the radiating beds are plane surfaces. Where the stones bed on to the boss, the joint is **conical**.

In Fig. 304, the beds are **conical** in form, and the joints are **plane vertical joints**.

Niche with Spheroidal Hood.—The body of the niche is formed of a semi-ellipse cylinder, and the hood is a quadrant of an oblate spheroid (see Fig. 301).

Draw the centre line NM, and the wall line and springing line at right angles in convenient positions, with O′ as centre and O′A′ as radius describe the semicircle A′D′B′.

Project A′B′ to the wall line in plan and describe the semi-ellipse ACB. With O′ as centre O′3′ as radius, describe semicircle forming the intersection of the conical bed of the boss and the surface of the hood. Divide the elevation into a suitable number of stones by pricking over the semicircle A′D′B′ with the dividers, and through E′ and F′ draw the beds radiating to the centre O′. Arrange the stones to suit the ashlar beds as at H′G′J′K′.

Project 3′ to the plan and make 3, 4 normal with the ellipse. Join 3 and 6 with a straight line. To draw the plan of the bed E, take a number of points in the ellipse as at 1, 2, and project them to the springing line.

With O′ as centre, O′1′ and O′2′ as radii, mark off the points 1*e*′, 2*e*′ on the bed E′. Project 1*e*′, 2*e*′ to the plan and the projectors intersect parallels with the wall line at 1*e* and 2*e*, which are points in the plan of the bed, through which a fair line may be drawn. The larger the number of points taken, the more accurate the curve. The plan of the bed F′ is found in the same manner.

To work stone No. 1, a **bed mould, face mould** and **reverse** are required, the two former being hatched in the drawing.

Work the bottom bed, the face, and the vertical joint square with each other. Apply the face mould to the front face and also to the back. Work the radiating bed and the top horizontal bed. Apply the bed mould to the bottom bed and the radiating bed, and work the joint adjacent to the boss, by first

working a circular draft from 3 to 3*e*, and trammelling the arris

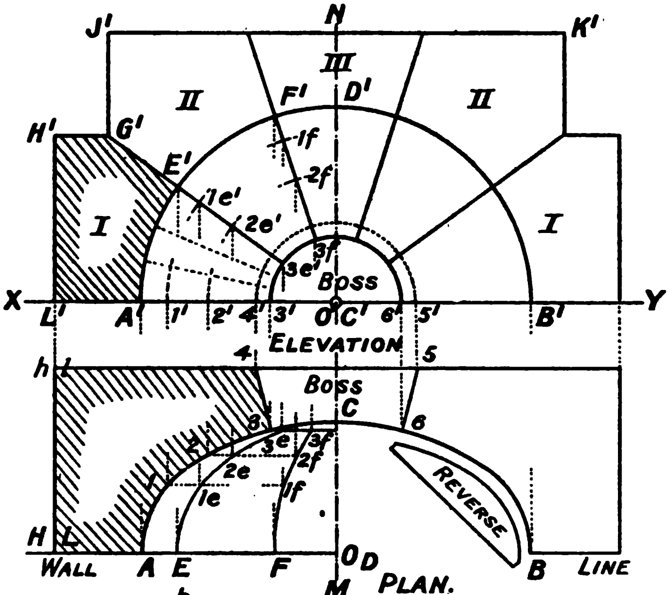
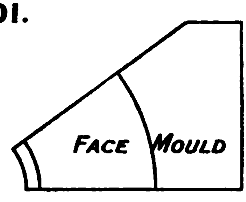
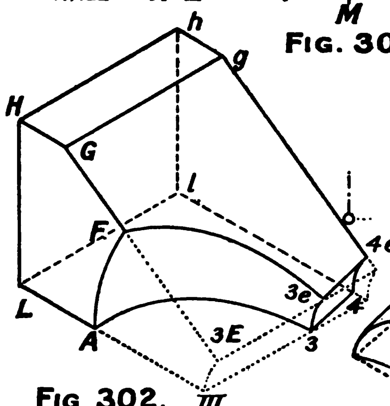


FIG. 301.





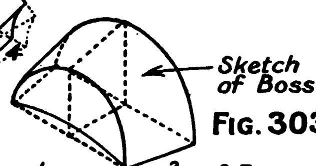


FIG. 303.

FIG 302.

Scale 12 6 0 1 2 of Feet

from the face. The circular curve 4,4*e* is scribed on the back from the boss mould, and the conical joint completed by working

drafts with a slightly rounded chisel from front to back, testing same with a straight-edge. The spheroidal surface is worked with the aid of a **reverse,** which must be applied along the radiating lines shown in Fig. 301, elevation. Fig. 302 shows the stone completed.

A face mould, back mould, bed mould and **reverse** are required for the boss, and reference to Fig. 303 should make the working quite clear.

Niche with Spherical Hood.—The body of the niche in this example is a section of a right circular cylinder, and the hood, the quadrant of a sphere.

The beds of the hood voussoirs are **conical,** the apices of the cones being at O. It is only necessary to set out half of the hood, as it is symmetrical.

Commence by drawing the centre line, the springing line XY at right angles, and the wall line in plan parallel to the XY, and at a convenient distance away from it. With O′ as centre and O′A′ as radius, describe the semicircle A′D′B′; with the same radius and centre O describe the semicircle in plan as at ACB. With the dividers, prick over the semicircle in elevation, and draw the joints radiating to the centre O′.

Join E′ E4, and F′F″ with horizontal lines, indicating the intersection of the beds, and spherical hood surface.

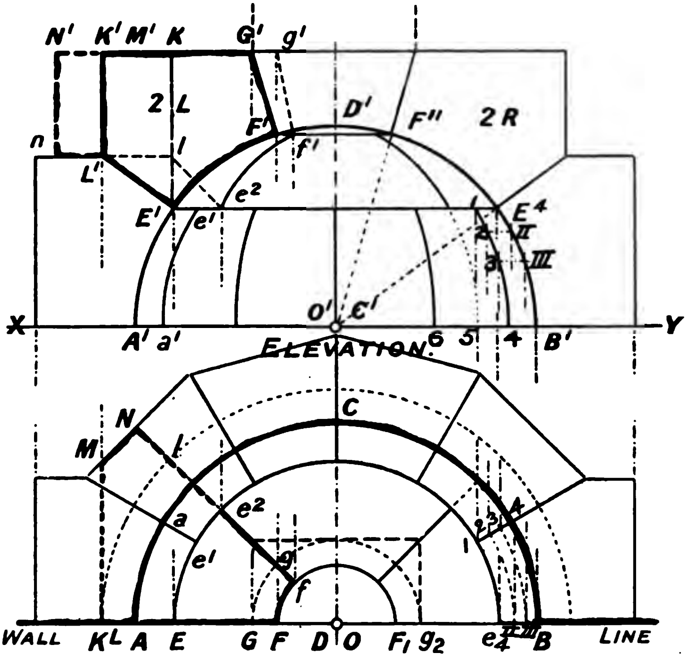
Draw projectors from E′F′ to the wall line in plan, as at EF, and with O as centre, OE and OF as radii, describe the semicircles indicating the intersection of the beds with the spherical surface, in plan.

The bottom or springing course is divided into six stones, and the second course into three stones, the joints being set out in plan.

The elevation of the joints will be sections of ellipses, and may be drawn by one of the methods already explained; O′D′ being the semi-major axis of all the curves, the semi-minor axes lying on the springing lines are O′4, O′5, and O′6.

The elevation of the joints may, however, be found by taking a number of points on the joint in plan, as at 1, 2, 3, 4, and with O as centre, O2 and O3 as radii, describing arcs of circles to the wall line at II, III. Project II, III, to the elevation, as at II, III, and draw horizontal lines, which lie on the surface of the hood. From 1, 2, 3, 4, in plan, draw projectors to the elevation, and the intersection of the horizontal lines and projectors, are points in the curve through which a fair line is drawn to represent the joint.

The elevation of the other joints may be found in the same



PLAN.

FIG. 304.

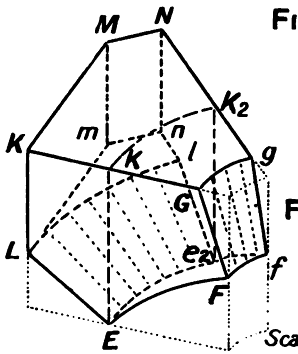


FIG. 305.

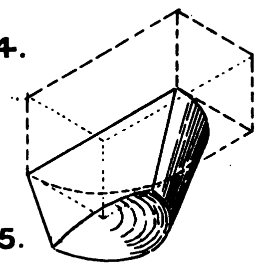


FIG. 306.

Scale 12 6 0 1 of Feet

manner ; but the elevation of these joints are not necessary on the setting out.

To work stone No. 2L, a **face mould** and **bed mould** are required, with a reverse template for working the spherical surface of the hood.

The face mould is shown in elevation N′, G′, F′, E′, *n*, this being the mould that would be applied on the **joint**, the portion K′, G′, F′, E′, L′ being applied on the **face**.

The bed mould is shown in plan N*f*FKM.

Work the top bed, and work the face square with the bed. Apply the bed mould, and work the other joints square with the bed. Apply the face mould on the face and joint, taking care that these moulds are scribed in their exact position. They may be tested for accuracy by boning, using KE as the boning line. Zinc templates should be made for the arcs of circles KK2—G*g*—and F*f*. Work a concave draft from F*f*, testing same with the template, and trammel the line F on the draft, from the top bed. Work the hollow conical bed by means of straight drafts from F to G, as indicated by the dotted lines; the chisel should be slightly rounded for this purpose.

It is only necessary to work a draft sufficiently wide, so that the line E *e*2 may be scribed with the aid of a template. The horizontal kite-shaped piece of bed is worked with the aid of a straight-edge, and the line L*l* may be tested with a concave zinc template, cut from the dotted line in plan. The convex conical bed is worked by a series of straight chisel drafts, from the line E *e*2 to the line L*l*, and the spherical surface worked with the aid of a convex zinc template, care being taken to see that the template is always applied on a meridian of the spherical surface.

Fig. 305 shows the completed stone.

The **keystone** is shown in Fig. 306, and may be worked as shown by the dotted lines in elevation and plan, to prevent sliding.

Vaulting

Vaults are chambers covered with arched ceilings, in stone, brick, or concrete.

In masonry the term **vaulting** generally refers to the ceiling only, and includes **domes, pendentive domes, barrel vaults, rib vaults,** and **fan vaults.**

Domes or **Cupolas.**—The surfaces of domes are usually generated by the revolution of a curve, and may be **spherical, spheroidal, ellipsoidal** or other surface of revolution. The inner dome of St. Paul's Cathedral, London, is said to be

generated by the revolution of a parabolic curve, the axis of which is inclined at $38\frac{1}{2}°$ to the central vertical axis of the dome.

Pendentive domes are domes set above square, rectangular, or polygonal chambers, the surface of the dome intersecting the vertical walls.

Fig. 307 shows a hemispherical surface cut by four vertical planes, and illustrates one of the forms of the pendentive.

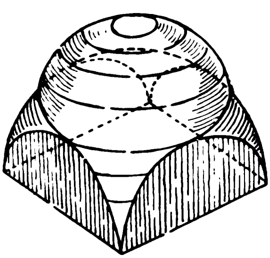


FIG. 307.

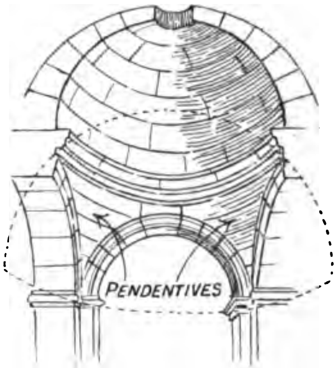


FIG. 308.

The pendentive dome may be set up on arches, the faces of the arches representing the vertical walls, the arches being known as pendentive arches (see Fig. 308).

A second dome is sometimes built upon the pendentive

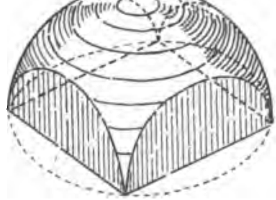


FIG. 309.

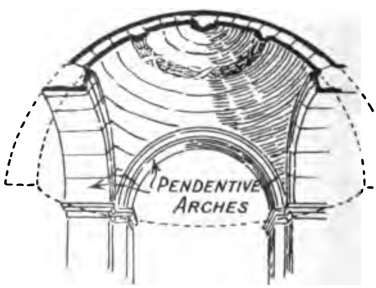


FIG. 310.

dome, and the hemispherical or other surface is then cut by a horizontal plane at the top of the intersections of the four vertical planes (see Fig. 309), thus forming a surface upon

which the second dome is built. The spandril pieces remaining are known as **pendentives** (see Fig. 310).

The second dome is sometimes built upon a vertical cylindrical *drum* to obtain increased height.

Barrel or **waggon vaults** are continuous arches, and are of little interest to the setter out, except where they wind or are intercepted by another vault, forming an angular intersection known as a **groin.**

When the intersecting vaults are formed of semicircular arches of the same radii, or of ellipse arches having their major and minor axes of the same dimensions, and the springing planes coincident, the groins are contained in a vertical plane.

When the vaults are of the same height, and the spans are different, the plan of the groin may be straight ; but unless the

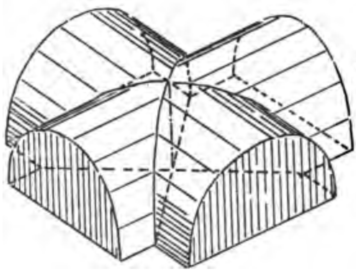


FIG. 311.—GROIN OF BARREL VAULT.

FIG. 312.—GENERAL SKETCH OF GROINS.

thicknesses of the walls are varied, the inner and outer intersection will not lie over one another.

When a smaller vault of less span and rise intersects a larger vault, the result is a shaped intersection or groin.

Fig. 311 shows the intersection of two semi-cylinders, illustrating the groin of a simple barrel vault.

Fig. 312 is a sketch of the interior of a barrel vault, showing the groins.

Rib or **rib and panel vaults** were introduced by the Gothic builders. Arches or ribs were first placed across the diagonal groins, the space to be covered being split up into a series of square or rectangular chambers by means of transverse arches (see Fig. 316).

These ribs enabled the builders to build the vaults with less centering than was required for those of the barrel type ;

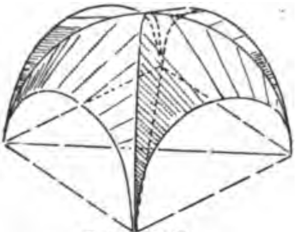


FIG. 313.
VAULT WITH SEMI CIRCULAR TRANSVERSE AND DIAGONAL RIBS.

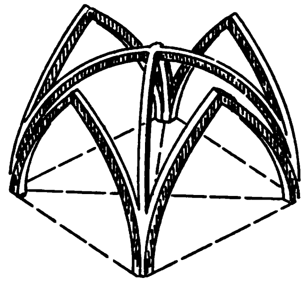


FIG. 314.
VAULT WITH SEMI CIRCULAR DIAGONAL RIBS AND POINTED TRANSVERSE RIBS.

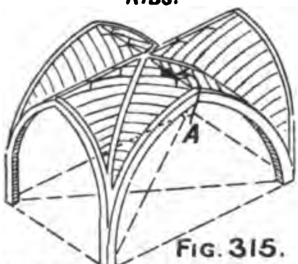


FIG. 315.
VAULT WITH POINTED DIAGONAL RIBS AND LEVEL RIDGE.

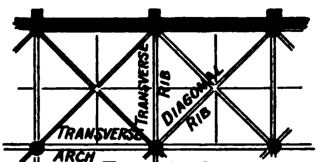


FIG. 316.
PLAN SHOWING THE AREA DIVIDED INTO CHAMBERS BY TRANSVERSE RIBS.

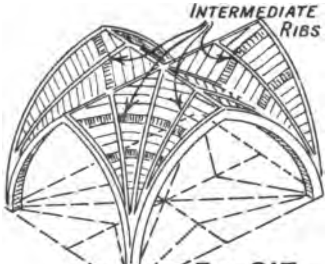


FIG. 317.
VAULT WITH RIDGE AND INTERMEDIATE RIBS.

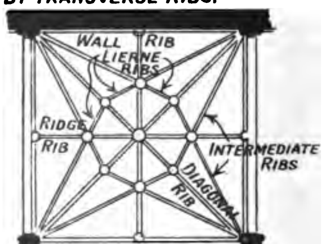


FIG. 318.
PLAN OF LIERNE VAULT.

they strengthened the groins and concentrated the loads on definite positions, the thrusts being counterforted by buttresses

outside ; and further, the builders were able to use small pieces of lighter and softer material between the ribs for **filling in.**

The **diagonal ribs** were in many cases semicircular, as were the **transverse ribs,** the greater length of the diagonal, and consequent larger semi, causing the vault to have a domical appearance (see Fig. 313).

Ribs were later arranged against the walls, usually following the shape of the pointed windows, and were known as **wall ribs** or **formerets,** and **ridge ribs** were placed at the top of the vault.

Later, when larger chambers were ceiled, ribs were built between the diagonal and wall ribs and the diagonal and transverse ribs, and known as **intermediate** or **tierceron ribs.** Smaller strutting or binding ribs were used at a later period called **lierne ribs** (see Fig. 318).

In nearly all cases the moulded ribs were masked by elaborately carved bosses at their intersections.

The system of building vaults with moulded ribs became so elaborate, and the ribs multiplied to such an extent, that their constructional value was ignored, and the ribs were worked on slabs of stone somewhat in the form of barrel vaults.

Fan vaulting, the last of the series of Gothic vaults, consists of a system of inverted hollow conoids, the ribs being of no constructional value, but merely worked upon the surface of the vault in some geometrical form for ornamentation.

Pendants were introduced into this form of vaulting, Henry VII.'s chapel at Westminster Abbey, London, being a very fine example.

A few of the more simple vaults are illustrated in the following pages.

Dome or Cupola

The dome illustrated in Figs. 319 and 320 is hemispherical inside, being described from centre C ; the outer surface is also spherical, and is described from centre C1. The beds are conical, the cones having a common apex at C. The joints are plane surfaces, the vertical planes containing them passing through the axes of the cones, plan at C2.

Commence by drawing a centre line *nm*, a line at right angles UV, and a line XY parallel thereto, to represent the springing plane.

With C2 as centre, describe the arc representing the plan of the inner sphere at the springing level ; with the same radius

and centre C, describe the arc A′B′, the section of the inner spherical surface. A′D′ at the springing level is 9 inches, B′*n*′ at the crown is 6 inches; find the centre C1 as previously described and draw the extradosial curve. Project D′ to the plan, and with C2 as centre, C2D as radius, describe the arc forming the plan of the outer surface at the springing level.

Divide the section into a number of voussoirs, and arrange the lantern. Draw the horizontal lines representing the elevation of the beds; the inside is shown with solid lines, the outside with dotted lines. Project the points E′, F′, G′, to the line UV in plan, and draw the arcs representing the plan of the beds; the inside is shown in solid lines, the outside in dotted lines.

Divide the bottom course, in plan, into a number of stones, 12 in the example, the bed mould being indicated by the points D2, E2, E3, D3.

Divide the second course into a number of stones, 12 in the example, taking care that the joints are arranged to bond with the courses above and below. The bed mould is indicated by the letters *e*4 F4 F5 *e*5. The description of the mould should be clearly marked on the zinc, with the number of stones required. The third course is divided into 6 stones, and the bed mould is indicated by the letters *f*2 G2 G3 *f*3. The bed mould of the top course is indicated *g*2 H2 H3 *g*3.

To Work one Stone of the Top Course

Stone required, 1′ 11″ × 1′ 4½″ × 10¼″.

Work the top surface as a plane of operation, and apply the bed mould (Fig. 321). Work the joints to the scribed lines, and square with the plane of operation. Apply the joint mould to the joints (Fig. 322), and work the concave cylindrical surface containing the nose of the moulding H2H3.

The line *h*2*h*3 may be trammelled from the nose, or a mould may be cut for it from the plan. It is not necessary to work the whole of the convex surface containing the arris *g*2*g*3; but it must be roughed off, and a draft worked with the aid of a concave reverse from the plan, so that the line may be trammelled from the operation plane; the outer surface may then be worked with the aid of the reverse (Fig. 324).

The line H4H5 can now be scribed on the concave cylindrical surface, and the surface containing the underside of the

moulding worked with the aid of a straight-edge, as at H5 H4 R (Fig. 322).

A draft should then be worked sufficiently wide to contain the lower arris of the stone, and the line scribed on with the aid

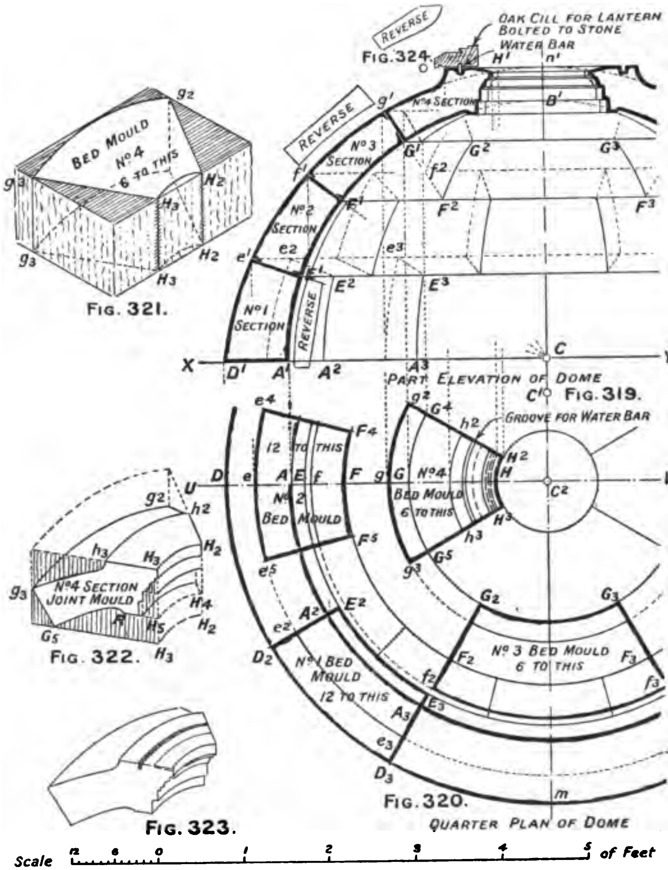


Fig. 324. Fig. 321. Fig. 319. Fig. 322. Fig. 320. Fig. 323.

of a template G4G5 taken from the plan. The under surface of the stone can then be worked with the aid of a reverse. The bottom conical bed is worked with the aid of a short, straight-edge, and the moulding completed.

The operations may be varied to suit the individuality of

the mason, but it is advisable that the elaborate part of the work, and that most easily damaged by subsequent operations, should be left until the last.

Fig. 323 shows a sketch of the completed stone.

The other stones are worked in a similar manner, and it is most important that the reverses for testing the accuracy of the spherical surfaces are held with their planes normal with the sphere. When the conical beds are worked, the straight-edge should be applied as explained for Fig. 305.

Pendentives

In Fig. 325 the pendentive is shown surmounted by a dome. The beds of the pendentive are level in the example, forming oversailing corbel courses.

The beds of pendentives are mostly conical, but the draughting and subsequent labour are much reduced by using level beds, and for small pendentives are quite suitable.

To avoid fracture of the sharp arris at the top bed of the pendentive, a chamfer has been taken off, and a small portion of the pendentive is worked on the circular cornice.

The joints of both the dome and pendentive are vertical planes, which, if continued, would meet at the common axis of the spheres indicated by C in plan.

Commence by drawing the centre line C*n*; a line UV at right angles, and a line XY parallel thereto, to represent the springing plane of the pendentive and the pendentive arches.

Set out the square E*e*FC, forming the quarter plan of the square chamber. With the diagonal C*e* as radius, and C1 as centre, describe the circle forming the pendentive, indicated in dotted lines in the elevation.

Set out the width of the arch soffits in plan, and draw the plan of the piers, shown hatched in example. With centre C1 and radius C1E′, draw the extrados of the pendentive arch. (Note that this radius is half the width of the square chamber.) Draw the intrados of the arch, and divide the arch into a suitable number of stones, 9 in the example.

Where the radiating beds of the arch stones meet the extrados, draw horizontal lines representing the level beds of the pendentive, as at 1, 2, 3, 4. Project these points to 1, 2, 3, 4 on the line *e*B in plan, and from C describe arcs of circles indicating the arrises of the beds.

The joints from these points 1, 2, 3, 4 in plan radiate to the centre C, the third course having one closer and the fourth course two closers. The elevation of these vertical joints

Fig. 324.

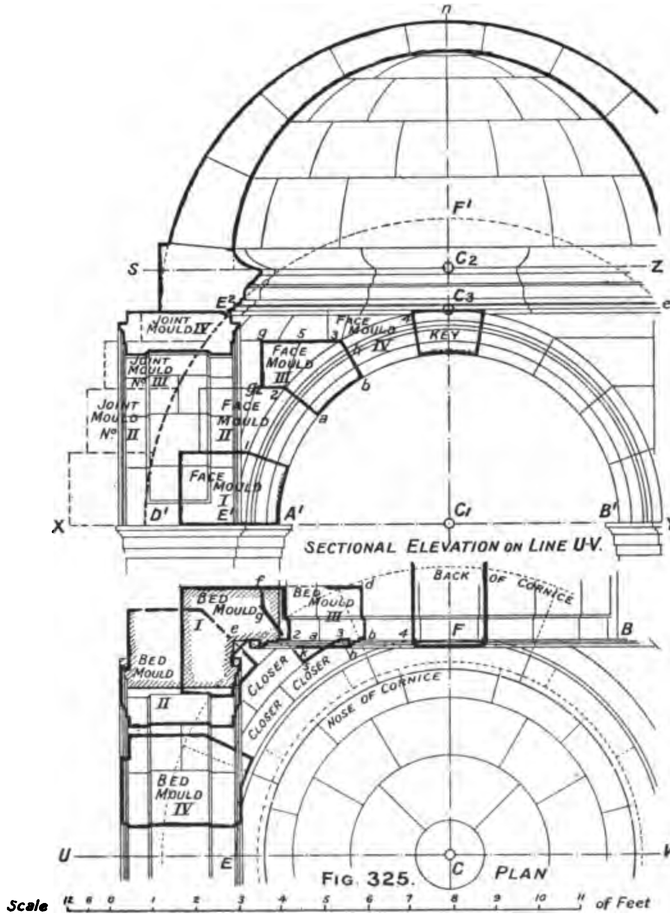


Fig. 325.

are sections of ellipses, and may be drawn as described for Fig. 304.

SZ, the top arris of the nose of the cornice, is the springing plane of the upper dome. C2 is the centre from which the

inner surface is described, and C3 the centre for describing the outer surface. The drawing may then be completed.

Moulds

The springer moulds consist of **top and bottom bed moulds**; **face mould No. I**; **joint mould**, consisting of a section of the arch moulding to apply on the radiating joints; and a **reverse**, cut to the dotted pendentive line D′F′ in elevation, for testing the accuracy of the small trinagular piece of pendentive, contained between the arch mouldings.

In the example the springer is jointed at the centre of the arches, the top bed mould being blacked and the bottom bed indicated by hatching.

Four stones would be required to these moulds.

No. II stone extends right across the pendentive arches, and includes a small portion of the pendentive.

Eight stones are required to these moulds, **handed**; or **4 "lines up,"** and **4 "lines down."**

No. III stone. The method of obtaining the moulds for No. III stone will serve as a guide for obtaining the moulds for all the arch stones, which are found in similar manner.

Points 2 and 3 are on the extrados of the arch, and are indicated in plan at 2 and 3; *a* and *b* are on the soffit, and are also shown in plan; 2 and 5 indicate the vertical plane joint of the pendentive. Continue this joint in plan to *g*; 2*g* measuring 12 inches in the example, being the tailing into the wall. *fg* is square with the back joint *fd*, which in this case is in the centre of the arch soffit.

The bed mould is therefore bounded by the points *f*, *d*, *b*, *h*, 5, *g*.

These points should be projected to the elevation, and the face mould is bounded by the points *g*, 3, *b*, *a*, 2, *g*2.

The joint mould No. III for the vertical joint of the pendentive is shown in dotted lines.

The moulds for No. IV are found in the same manner, the stone in this case being the full width of the arch.

The face mould of the keystone is shown in elevation; a bed mould is not necessary. Care must be taken to see that the small piece of pendentive is contained on this stone; it is indicated in black on both face mould and bed mould.

To Work Stone No. III

Stone required, 2′ 5″ × 1′ 10″ × 1′ 10″.

Work the top bed and apply the bed mould; work the back joint square with the bed, and roughly surface the face to enable the face mould to be applied (see Fig. 326).

Work the radiating beds and the small piece of level bottom

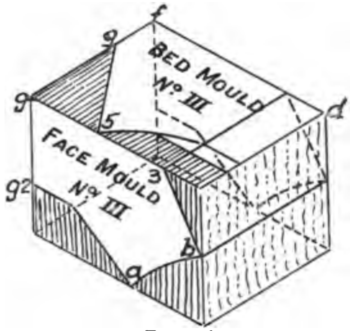


Fig. 326.

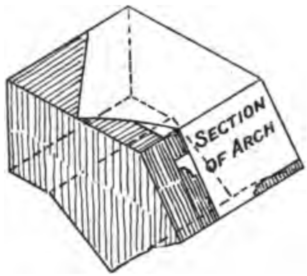


Fig. 327.

bed. Apply the section mould to the radiating beds (see Fig. 327).

Work the vertical joint of the pendentive and dress the arch surface to the face of the nosing (see Fig. 328). The moulding

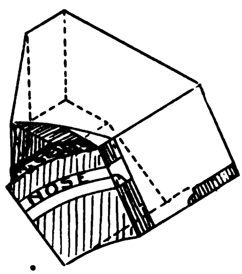


Fig. 328.

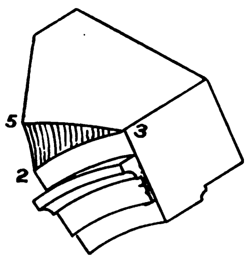


Fig. 329.

may now be worked with the aid of the sinking square and reverse templates.

The triangular piece of pendentive is worked with the aid of a reverse, the line 2, 3 at the top of the band being tested with a reverse template from the face mould.

Fig. 329 shows the stone completed.

Barrel Vault

The example shows the intersection of two vaults at right angles, the smaller vault being semicircular and of 5′ 0″ span; and the larger vault of 6′ 0″ span, but of the same rise (Fig. 330).

It is only necessary to set out rather more than quarter so as to obtain the keystone.

Commence by drawing the axial lines *nm* and *uv* at right angles to each other, and at a convenient distance the springing lines XY, *xy*.

With C as centre and CA = 2′ 6″ as radius, describe the soffit of the smaller vault. With the same centre and CB as radius, describe the extrados of the vault.

Divide this section into a convenient number of voussoirs, 9 in the example, the beds radiating to the centre C and intersecting the soffit at D, E, F, G. H.

Set out half the span *ca* of the larger vault, on the line *xy*, and make the rise *ck* equal the rise of the smaller vault.

Draw the plan by projecting the point *a* square with the *xy*, as shown in the example by dotted lines. Project A from the smaller vault at right angles to XY until it intersects the former at *a*2. Draw a line from *a*2 to *c*2, the intersection of the axial lines representing the plan of the intersection of the cylindrical surfaces. Project DEFGH to this line, indicated by *d*2, *e*2, *f*2, etc.

Project these points at right angles to *xy* to the section of the larger vault, and measuring from the smaller vault, make the points the same height above *xy*, as at *d*, *e*, *f*, *g*, *k*, *h*. A line drawn through these points will be an ellipse, and will be the soffit of the larger vault.

The extrados may be found in a similar manner, but it must be noticed that the diagonal intersection in plan *does not* lie over the internal intersection.

To obtain a good curve, intermediate points should be taken and projected in the same manner described.

The beds on the extrados are shown solid in plan, whilst those on the intrados are dotted.

Bed moulds are required only for those stones containing the groins, and the vertical joints may be placed in any convenient position, so long as the stone is made to contain ***both the inner and outer intersection*** of the vault surface.

To work Stone No. IV containing Part of Groin, 2 Lines up, 2 Lines down.

Stone required, 1′ 9″ × 1′ 11″ × 1′ 3″.

Work one of the surfaces as a plane of operation, and apply

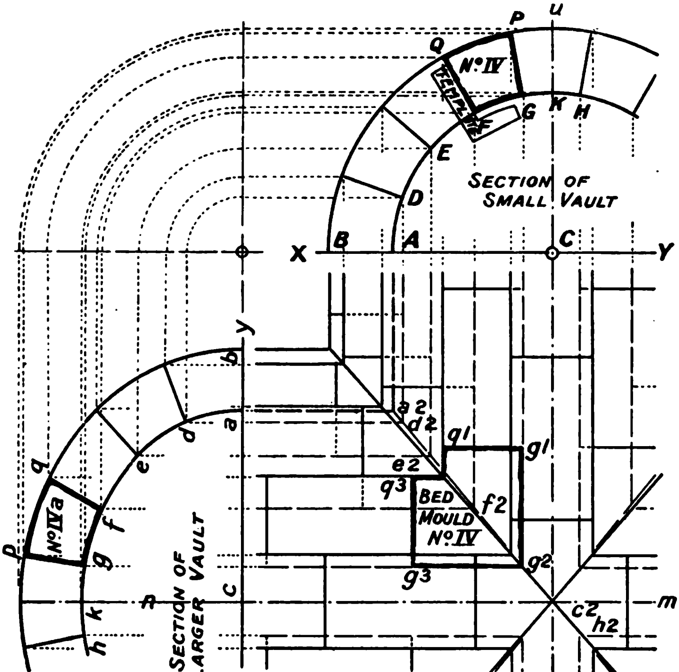


Fig. 330.

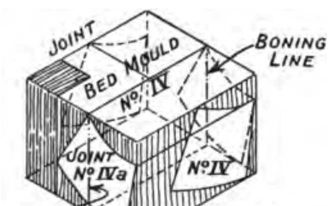


Fig. 331.

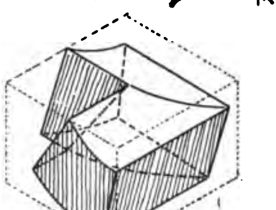


Fig. 332.

Scale 12 9 6 3 0 1 2 3 4 5 6 of Feet

the bed mould. Square the joints from this surface, and roughly surface the opposite ends to apply the joint moulds. Scribe the joint moulds on the joints, and apply them to the opposite ends, boning them to ensure accuracy.

The soffit may then be worked for one vault; a mitre line, as before explained, is drawn on the soffit, and the other section of the soffit is worked to the scribed joint and the mitre line. The top radiating bed is worked in a similar manner, and tested for accuracy by boning.

Care must be taken in working the bottom beds, as these radiating beds intersect each other in an **internal angle**.

Templates may, however, be cut to assist the mason in working (*see sections*, Fig. 330).

The template for the semicircular vault will apply on all the courses of that vault; but templates must be cut for every joint of the larger vault.

The extrados is worked with the aid of reverses and straight-edge, the intersection being an internal angle. The reverse for the semicircular vault is common to all stones; but separate reverses are required for each stone of the larger vault, and they must be carefully marked, not only for the particular stone, but also for **top** or **bottom,** owing to the variation of the ellipse curve.

Fig. 332 shows the completed stone, intrados up.

Rib and Panel Vault

In this example (Fig. 333) the vault is built over a square chamber, with semicircular diagonal ribs, and pointed wall ribs of the same radius as the semicircle.

The wall ribs do not rise to the same height as the diagonal ribs.

It is only necessary to set out one quarter of the plan.

Commence by drawing the axial lines A*a*, B*b* at right angles to each other, and draw the wall lines W*w* parallel to them.

Draw the centre lines of the diagonal and wall ribs *xy* and DD, *dd*.

The full wall rib is shown in the example, but only half the rib may be used, and in such case the centre lines of the rib will coincide with the wall line.

The centre of the shaft is on the intersection of the centre line of the ribs; draw the circles representing the plan of shaft, the abacus of the cap, and position at which the noses of the ribs spring from the cap.

Cut a full-size template of the rib section and apply it to the plan, keeping the centre line of the template on the centre line of the rib, and the nose of the rib in the desired position on the cap. If this template is marked from the centre line of each rib, the plan or bed mould of the bottom springer will be obtained.

Use *xy*, the centre of the diagonal rib, as the springing line, and from C as centre, C*n* as radius, describe the nose of the rib in elevation.

Draw a springing line XY at a convenient distance from the plan, and project *e* to E, the springing point of the rib. From E, and with radius *n*C, mark off the centre C2 and describe the nose of the wall rib.

The arris of the chamfer, the filling in line, and the extrados of the ribs may now be drawn from the same centres.

Set out the width of the ribs in plan and draw lines parallel to the centre lines. The vertical faces of the ribs meet at the points GG in plan; project them to G1 on the diagonal, and G2 on the wall rib elevations.

Through these points G1 and G2 draw the radial bed joints, and note that the mouldings of the ribs are entirely clear above this line, and that the ribs have separate existence.

The level bed is taken from the point where the radial bed meets the extrados of the rib. The intermediate level bed is placed in a suitable position.

Specially note that the heights HH and hh of the beds on each elevation must correspond.

Joint the ribs above the level bed, allowing for a suitable keystone at the crown of the diagonal ribs.

Fig. 335 is a section through the vault on the line A*a*, the heights being set out from the line XY. The filling in is cambered on the under surface, one quarter of an inch to a foot, and the beds are at right angles to a line bisecting the lower angle of the panel.

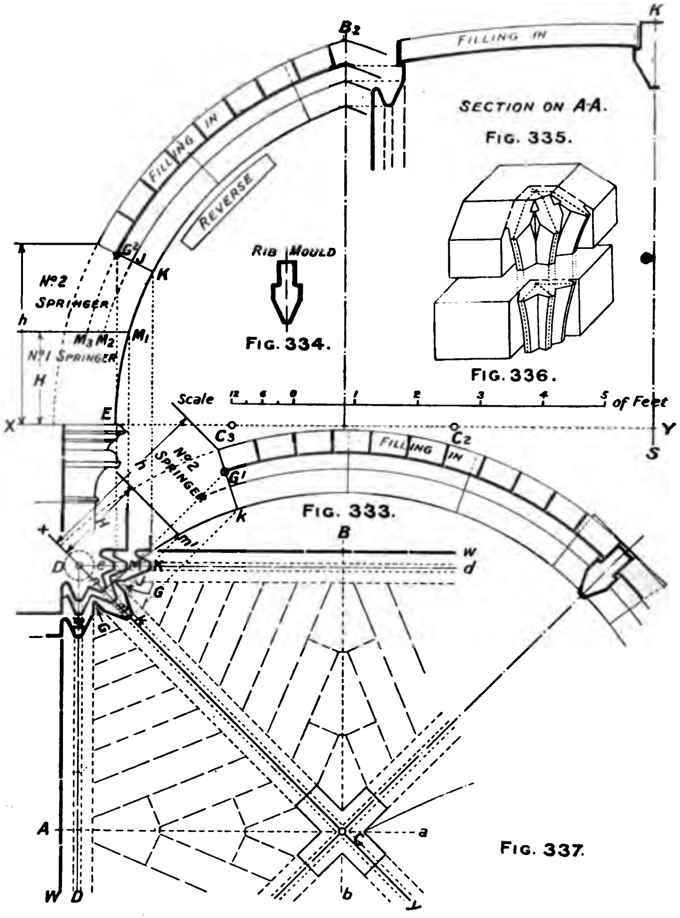
There is no fixed rule for placing the beds of the filling in. The English mason of mediæval times generally arranged his "filling in" with parallel courses, leaving kite-shaped stones at the ridge; whilst the French mason usually shaped his courses so that they met with a straight joint at the ridge.

To obtain the Moulds

The bottom bed mould for No. I. **springer** has already been described. The top bed mould for this springer is found by

projecting M′ on the elevation of the wall rib to M in plan, and *m′* on the diagonal rib to *m* in plan.

The section of the rib at this level bed is elongated owing to the bed not being normal to the curve of the rib; and the



use of the rib mould to find this bed mould is not strictly correct, although frequently used by the setter-out. A raking mould of the rib should be cut at this level, or the points M2, M3 may be projected to the plan.

For elaborate mouldings a raking mould is the best expedient, and if the nose of the raking mould is placed on the plan of the ribs at the M*m*M, the outline of the moulding will intersect and give the correct contour of the moulding at this bed.

The top bed mould of No. 1 springer is the bottom bed mould of No. 2 springer. The top bed mould of No. 2 springer is found by projection, and may be easily followed by referring to the drawing.

The vertical joints of the springers should be arranged to bond with each other and with the wall. A sketch of the two springers is given in Fig. 336.

Fig. 337 is a sketch of the keystone of the diagonal ribs.

To work No. 2 Springer

Work the bottom bed, square the joints, and work the top level bed. Apply the bed moulds, taking care that the

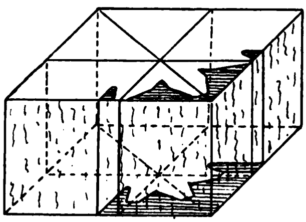


Fig. 338.

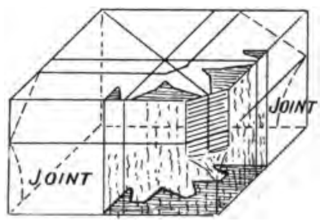


Fig. 339.

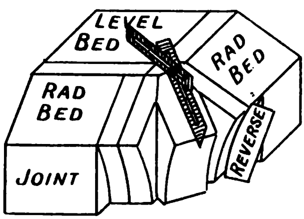


Fig. 340.

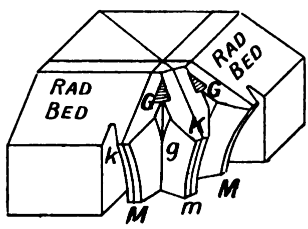


Fig. 341.

centre lines of the ribs are in their correct position (see Fig. 338).

Apply the joint moulds to the back joints. Work a draft square with the level bed at the front arris of the nose of the

diagonal rib; square the centre line of the rib on this draft, and gauge the front arris of the rib from the top bed (see Fig. 339).

Work the radiating beds with the aid of the shift stock and to the back joint mould. Scribe the centre lines of the ribs on the radiating beds; and apply the rib moulds.

Work the nose of the ribs with the aid of a reverse (Fig. 340).

If the ribs are elaborately moulded, sinkings are made from the nose of the rib and tested with reverses and gauges.

The sides of the ribs are vertical planes, and G*g*, the line of intersection, is vertical.

TRACERY

Tracery windows are of infinite design, but there are two distinct kinds.

1. **Plate tracery,** which originated with the early Gothic builders, consists of a group of two or more narrow windows under a main arch, the space between the smaller and the main arch, and known as the **tympanum,** being pierced with a circle, trefoil, quatrefoil, or other geometrical pattern.

Fig. 342 illustrates a typical example: the two **lights** are separated by a chamfered mullion and arched with equilateral arches. The tympanum is pierced with a quartrefoil, and the interior of the window has a rere arch.

The setting out of this window is not difficult, and the reader is referred to the chapter on arches and to the description of the rere arch in the earlier pages of this book.

2. **Bar tracery** is a development of plate tracery; and the mullions, often most elaborately moulded, split or grew into geometrical forms in the head of the window.

These curved mouldings are known as **monials,** and often split into smaller mouldings, springing from the fillet (see Fig. 345).

The design of the bar tracery is infinite. In the earliest examples circles with trefoil, quatrefoil, cinquefoil, etc., were used. Later the design was less rigid, and took curved geometrical forms of a more or less flamboyant appearance.

The latest examples of Gothic work have slender upright members in contact with the curves, and were common to the perpendicular period.

Fig. 343 is an illustration of the earliest type of bar tracery, the construction lines being clearly shown.

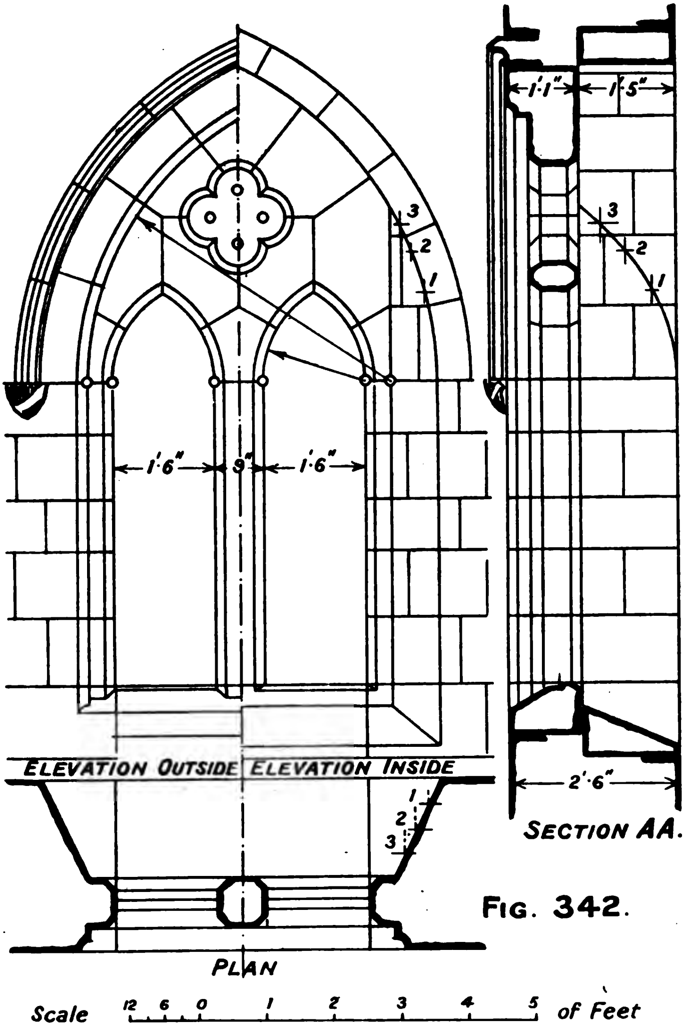


FIG. 342.

Fig. 344 is an illustration of a **flamboyant window.**
Fig. 345 illustrates a window of the perpendicular type.
The construction lines are shown on all examples, and a

description of the window illustrated in Fig. 345 will serve as a guide to the general setting out of tracery.

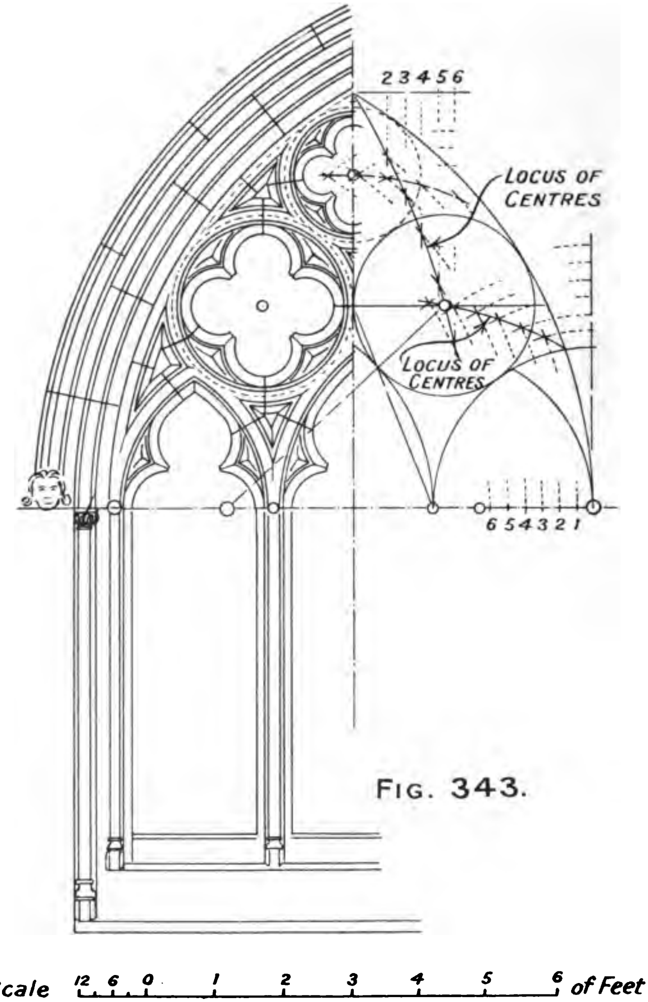


FIG. 343.

Draw the centre line and springing line of the main arch, and draw the arch, a four-centred Tudor arch, as previously

described. Draw dotted lines to represent the centres of the mullions, and carefully note that the mullions A and B are of different widths. From centres C describe the curves leading

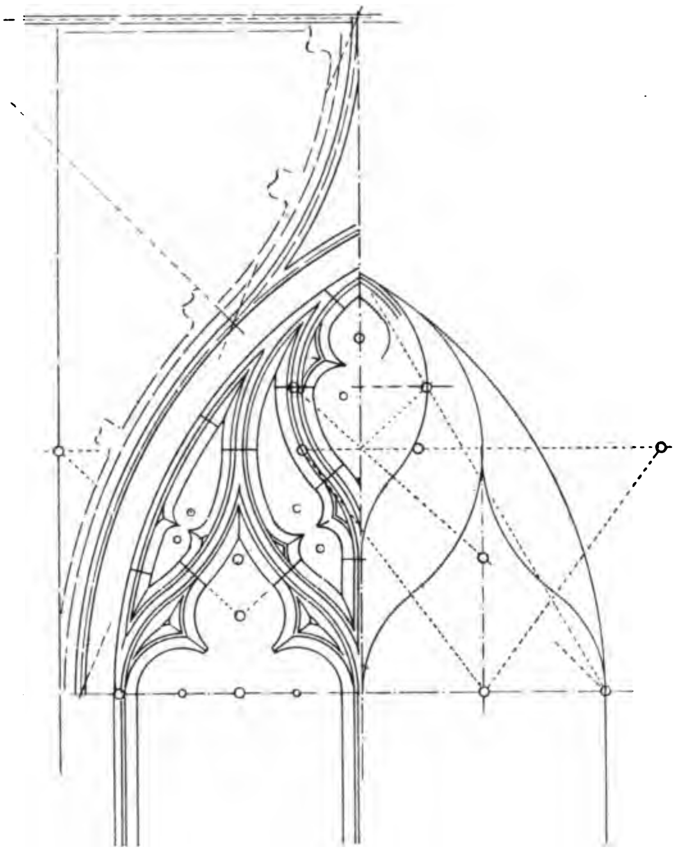


FIG. 344.

Scale 12 6 0 1 2 3 4 *of Feet*

from the jambs and centre mullion. Draw a second springing line parallel with the first, but some distance below. Describe the centre lines of the ogee arches, the centres being found as

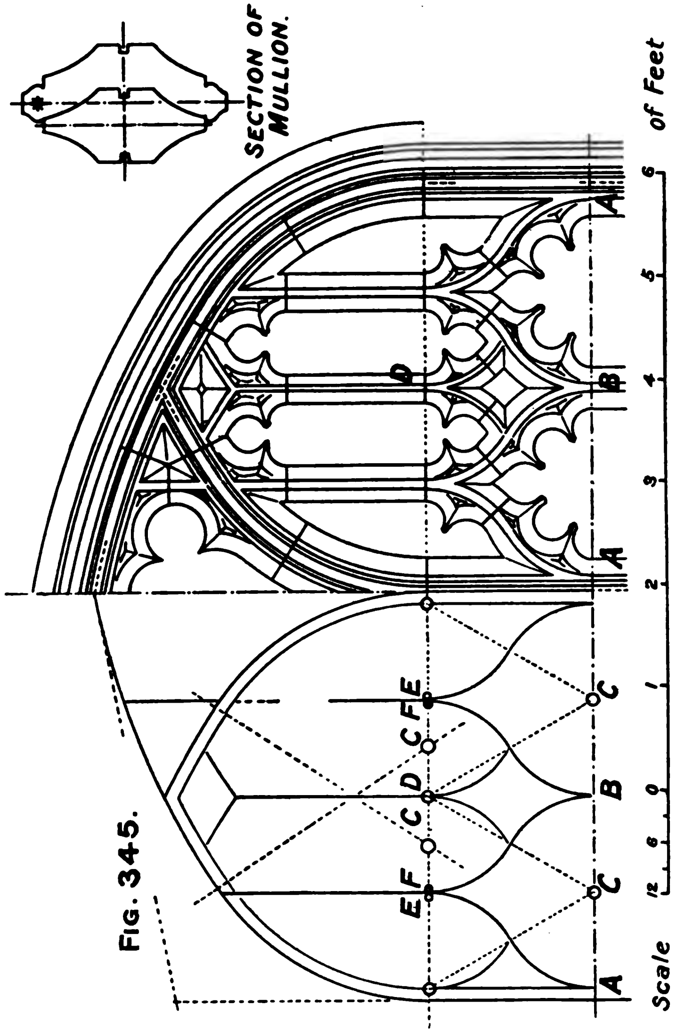


Fig. 345.

previously described, and note that the centres in this instance are taken on the fillet, and not on the roll.

The monial is again reduced at the sub-divisions of the

window, marked D on the illustration ; centres are shown as E and F. The cusps and foils are found by trial and error. Cusps are of varying form, and are shown in Fig. 348.

A general method of describing the foils and cusps is shown

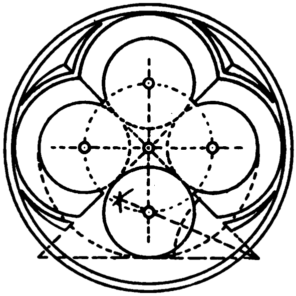


FIG. 346.

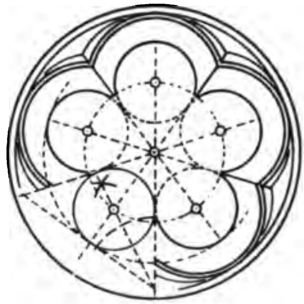


FIG. 347.

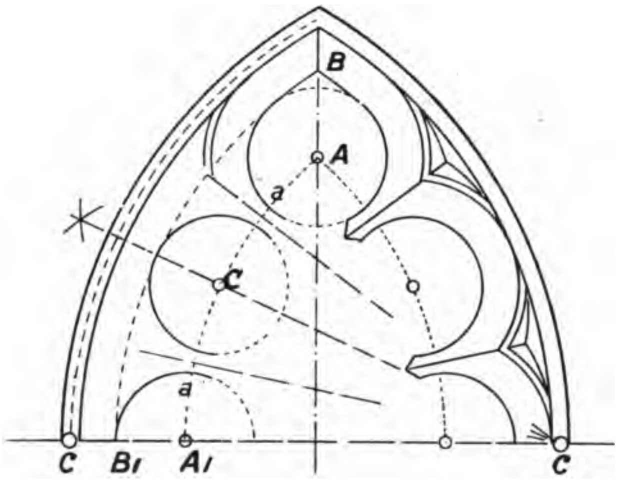


FIG. 349.

in Fig. 349, but both foils and cusps are often drawn in freehand, or made of different sizes in keeping with the design.

Describe a trial dotted line as at AA1, BB1 being the edge of the monial. With distances A1 B1 in the dividers, step off the curve AA1. In the case of a cinquefoil, the curve AA should measure four times A1 B1 plus twice the thickness of the cusp, and the curve AA must be adjusted until correct.

With centre A1 and radius A1B1, describe the bottom foil; with A as centre, and the same radius, describe the top foil. Bisect *aa*, and the bisection line intersects A1A at C, the centre of the middle foil. The cusps may be finished to one of the designs shown in Fig. 348.

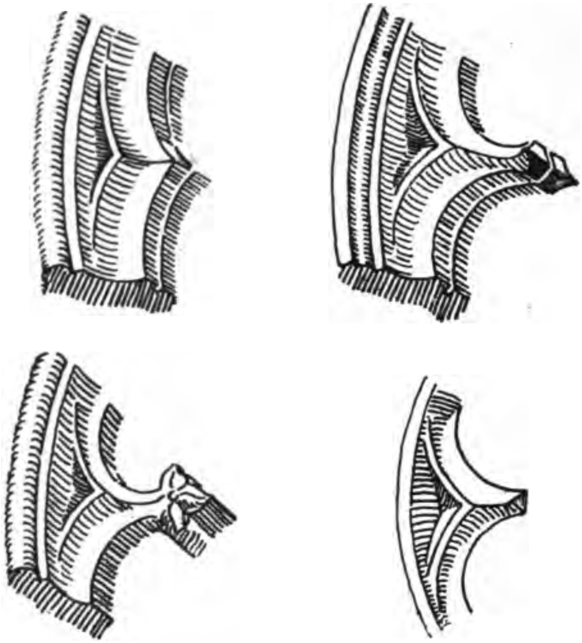


FIG. 348.—CUSPS.

Figs. 346 and 347 show respectively a **quatrefoil** and **cinquefoil.**

TO WORK SPRINGER OF WINDOW (FIG. 345)

Work a plane surface of operation, scribe the face mould on this surface, and square the joints. Square the centre lines on the joints, and apply the mullion and monial moulds, taking care to see that the moulding with the nosing marked * is always applied in one direction. Thickness the stone, and apply the face mould to the other side. Work the foils right through (see Fig. 350).

Scribe the nose on the faces of the stone with zinc templates. Trammel the arrises of the mouldings, round the cusps and

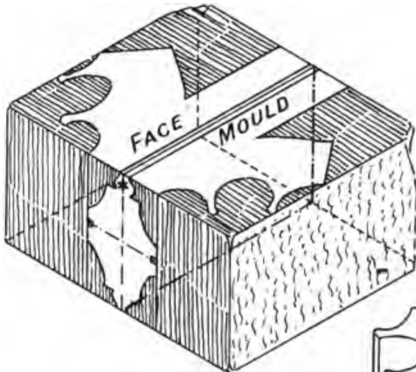


Fig. 350.

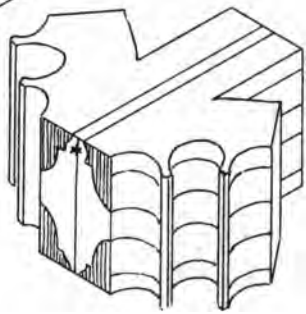


Fig. 351.

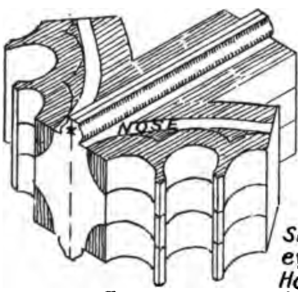


Fig. 352.

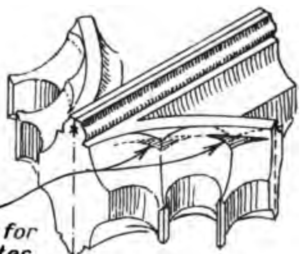
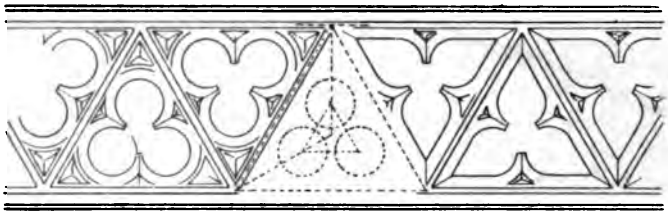


Fig. 353.

Working a Tracery Springer.

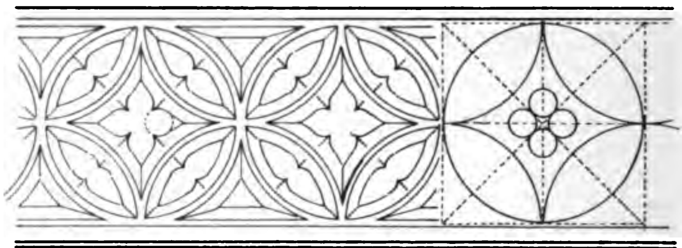
foils (see Fig. 351), and work the second surface of operation.
Work the hollow chamfer round the foliations (see Fig. 352). Scribe the depth of the fillet to receive the eye, on the hollow

chamfer, and sink to the surface (Fig. 353). Work the eyes and complete the springer by working the grooves to receive the glass.



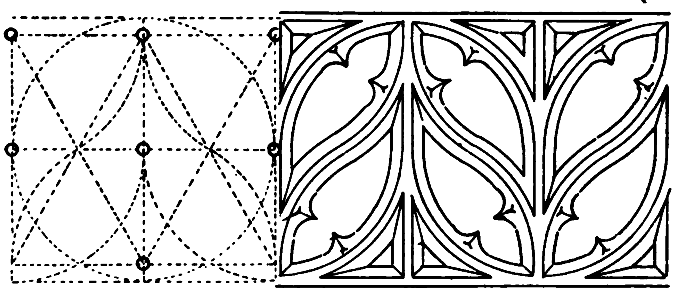
EQUILATERAL TRIANGLE AND CIRCLE

FIG. 354.



SQUARE AND CIRCLE

FIG. 355.



SQUARE, EQUILATERAL TRIANGLE, AND CIRCLE

FIG. 356.

Figs. 354, 355, and 356 are repeating designs suitable for pierced parapets or sunk margins.

Fig. 354 shows two trefoil designs, the basis lines being the same.

Figs. 355 and 356 show designs based on the square and circle.

APPENDIX

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATION PAPERS

WRITTEN EXAMINATION, 1909.

N.B.—The answers ought to explain the matter in question quite fully and plainly, without being too long. Sketches, whether drawn freehand or with instruments, ought always to be made approximately to scale.

ORDINARY GRADE.

1. What qualities would you look for in selecting stones (*a*) for external dressings, (*b*) for copings, sills and other weatherings, (*c*) thresholds, (*d*) templates and bases, and (*e*) internal decorative work ? (*10 marks.*)

2. Give a list of six building stones which you are acquainted with and indicate their individual characteristics. (*12.*)

3. What constitutes the difference between what are known as free (*e.g.*, Bath, Beerstone, etc.) and hard stones (*e.g.*, Portland, York, etc.) ? and describe the method and apparatus needful for cutting and shaping each. (*12.*)

4. Describe briefly the various materials used for the composition of mortar, the tests applied to each material, and the proportions of each and methods of mixing ; and state what precautions you would take to prevent discolouration of stone facings. (*12.*)

5. Show by a diagram how you would convert a rough hewn block, 6 ft. by 4 ft. on bed and 3 ft. 6 ins. high, in order to provide jobs to make the following stones :—2 thresholds, 4 ft. by 12 ins. by 4 ins. ; 2 window sills, 6 ft. by 12 ins. by 4 ins. ; 4 window sills, 3 ft. by 12 ins. by 4 ins. ; 4 templates, 12 ins. by 12 ins. by 4 ins. 2 jambs, 6 ft. by 12 ins. by 8 ins., in two lengths ; 2 mullions, 6 ft. by 18 ins. by 11 ins., in two lengths ; 2 heads, 7 ft. by 12 ins. by 8 ins., in two lengths ; 2 heads, 3 ft. 6 ins. by 12 ins. by 8 ins., and the remainder in 12-in. by 4 in. coping, stating how much of the latter you would have available with the minimum waste. (*12.*)

6. What is meant by the " natural bed " ? What relation should it bear to the finished article, and why ? (*10.*)

7. State the principle to be adopted in settling the bond of stone facings, whether in ashlar or string coursed work or in rubble facings. What precautions would you adopt in setting to avoid flushing and fracture, more particularly in piers and other weight-carrying stones, also in sills and thresholds ? (*11.*)

8. Name six types of stone facings (either for hard or soft stones, or both), and describe the tools necessary to produce the same. (*12.*)

9. Draw, to a scale of $\frac{1}{8}$ in. to a foot, the gable of the west end of a church, 28 ft. wide, with a pitch of 60°, with a three-light geometrical tracery window. Give a plan and section and detail of the springer and kneeler, and full-sized moulding of the mullion. The wall to be faced externally with squared random Kentish rag and internally with Bath stone ashlar. (*14.*)

10. Indicate, by sketches, the best and most weather-proof method of jointing and securing stonework in ashlar, coping, cornices, mullions, and jambs. What materials would you use? (*12.*)

11. Name, and illustrate by diagrams, six classic mouldings in general use, also a like number of Gothic mouldings. (*12*).

12. Describe and illustrate four types of rubble wall facing. State what additional wall thickness, if any, you would provide to afford as much strength as is possessed by a wall of coursed stone bond, and show by sketches the type of pointing you would use for such a wall face. (*16.*)

WRITTEN EXAMINATION, 1910.

ORDINARY GRADE.

1. Shortly describe the colour and characteristics of the following six building stones:—Hopton Wood, Darley Dale, Ham Hill, Dumfries, Pennant, Aberdeen granite, and state for what purposes you would consider them most suitable. (*12 marks.*)

2. How would you cut up and work each of the stones named in Question 1? Describe the tools to be employed, and give sketches of same. (*10.*)

3. Name six stones which you would use for internal decorative work requiring fine treatment with small mouldings. State their characteristics in respect of colour and composition. Say why you have selected them, and give instances of any notable buildings where they have been so used. (*12.*)

4. State how you would cut up and work each of the stones quoted under Question 3, describing and sketching the tools to be employed. (*10.*)

5. Indicate the difference between a sandstone and a limestone, giving the characteristics and composition of each. State for what purposes in a building each is, in your opinion, most suitable. (*12.*)

6. How would you ascertain the natural bed of a stone block? State why this is a matter of importance in stone construction. (*10.*)

7. What mortar do you consider the best for the setting and jointing of masonry? Of what materials should it be composed, what characteristics would you require in connection with the same, and what tests would you employ in proof thereof? (*12.*)

8. What is the cause of discolouration often to be seen in stone-walling, and how is this to be guarded against? (*10.*)

9. What weight could you safely put upon nave piers 2 ft. 3 ins. diameter, constructed of the following stones:—Portland, Box ground Bath, Bramley Fall York, Ancaster, red Mansfield, and

Cornish granite ? State the minimum height you would adopt for each stone, what bedding you would use, and what precautions you would take to prevent flushing or fracture. (*15.*)

10. Draw sections of the following twelve mouldings :—Cyma recta, Astragal, Roll and triple fillet, Echinus. Birdsbeak, Ovolo, Double Ogee, Torus, Sunk Chamfer, Listel, Scroll moulding, and Scotia. (*12.*)

11. What is the safe load per foot super. that can be put on the following natural ground :—(*a*) Natural bed of soft clay or wet or loose sand ; (*b*) natural bed of ordinary clay or confined sand ; (*c*) natural bed of compact gravel, London blue clay or chalk ? What spread of footings would you give to a wall 1 ft. 6 ins. wide, supporting a load of 15 tons to the foot run, on each kind of ground ? (*10.*)

12. You have to erect upon a two-brick wall, 40 ft. above ground and 40 ft. long, a cornice, 36 ins. on bed by 15 ins, high, with stones each not less than 5 ft. long, and only the ordinary bricklayers' scaffold has been as yet provided. How would you set about it, and what appliances would you provide to effect the desired result in the speediest and most economical method, no power appliances being available ? (*15.*)

Written Examination, 1911.

Ordinary Grade.

1. Name six building stones which, in your opinion, possess the best weathering qualities and greatest strain capacity. State the resisting power of each ; describe shortly their characteristics, and state for what position in a building each is most suitable, and for what reasons. (*12 marks.*)

2. What mortar do you consider the best for setting masonry without leaving any stains in or on the stone ? State the materials of which it is composed and what qualities you would look for in such materials, and what tests you would impose in proof thereof. (*10.*)

3. Why is concrete introduced into foundations ? What ingredients would you use to produce the strongest kind of concrete, what qualities would you require in them, and to what tests should they be subjected ? (*10.*)

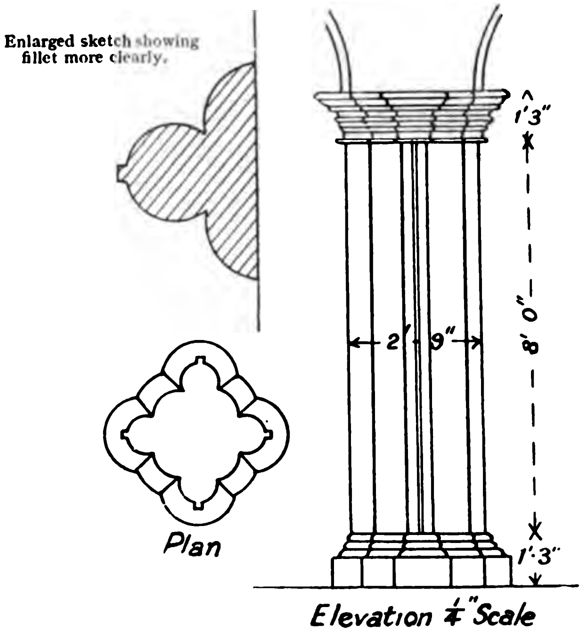
4. Draw a ¼-in, scale section of a 1½-brick external wall and basement floor, the level of which is 4 ft. 6 ins. below the ground surface ; show an inch boarded floor on wood joists and sleepers with all that is necessary to comply with modern building by-laws, both as to ventilation and the prevention of damp both from below and from the adjacent earth. (*12.*)

5. In refacing an old brick building with 6-in. stone ashlar work, what percentage of bonding stones would you employ, and how would you ensure perfect combination ? The wall being 18 ins. thick at bottom and 14 ins. at top, and it being impracticable to add to its thickness, what processes would be necessary to achieve the result required and what precautions (if any) would you take to guard against damage to the structure, both internally and externally ? (*15.*)

6. Show sections of the following mouldings :—Wave moulding, hollow chamfer, cavetto, roll and triple fillet, astragal, pointed bowtell. Also draw sections and sketch elevations of three pier caps and three bases in common use by the Norman builders. (*12.*)

7. Indicate, by description and sketches, six types of rubble stone wall facing with brick backing, say what method you would adopt for efficient bonding and how you would point the joints. (*12.*)

8. If the wall described in the last question be constructed with a cavity, what form of tie would you use to connect the outer stone with the inner brick thickness ? State what means you would adopt to prevent damp percolating at the sides and top of openings and also at the base of the wall. (*8.*)



9. Describe the apparatus necessary to hoist and fix by hand labour a stone cornice to a building 60 ft. high, the stones being 4 ft. 6 ins. long by 1 ft. 6 ins. high by 12 ins. upon the wall, and 21 ins. projection beyond the wall face. What precautions would you adopt to ensure stability until the blocking course or walling over is placed in position ? (*12.*)

10. If you had to sink a foundation for a 22-in. wall through soft ground in order to reach a hard bottom 6 ft. below the surface, what means would you adopt to secure the ground at the sides of

the trenches in the following soils :—(*a*) Peat, (*b*) yellow clay, (*c*) alluvial mud, (*d*) running sand ? (*10.*)

11. Describe the kind of block you would select and indicate by a sketch how you would cut it up, in order to produce, with the greatest economy, cornice stones 27 ins. high and 42 ins. wide, 18 ins. of which stand on the wall ; indicate which would be the natural bed of the stone, why you would so cut the block, and say how you would detect this bed in the stones with which you are familiar. (*12.*)

12. What is the ruling principle to be observed on measuring the cubic contents of a piece of stone worked and ready to fix ? State the total cubic contents of the stone pier in the diagram given below. (*10.*)

(*For sketch, see page* 178.)

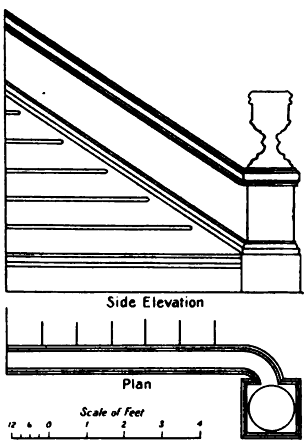
Written Examination, 1912.

Grade I.

1. Separate the following building stones under the heads of " Sandstones " and " Limestones," placing them in their order of durability, the most durable first. State what method you would employ in determining their natural bed :—Kenton, Darley Dale, Hollington, Woodhouse, Chilmark, Beerstone and Purbeck. (*10 marks.*)

2. Describe the method you would adopt in testing a specimen of limestone in order to ascertain its suitability for producing hydraulic lime. State how this latter is manufactured and for what specific purpose. (*9.*)

3. Show on diagram the method you would adopt in jointing a ramp wall, partly circular on plan. The pier at the bottom being



small, it is desired as much as possible to minimize the thrust thereon and to obviate all acute angles in the joints. Number the stones thus set out for ready and correct fixing. (*12.*)

4. Illustrate by sketches to ½-in. scale, stones, 1 ft. 6 ins. by 1 ft. high, with the following types of finished face:—Vermiculated; hammer dressed; the like with drafted margin; furrowed; tooled; pointed. (*12.*)

5. Enumerate the tools in common use by masons in connection with converting from block, cutting and working, (*a*) soft, and (*b*) hard stones, illustrating by sketches. State under which class you would place the following varieties of building stones:—Weather Bed Ancaster, Bramley Fall, Caen, Ham Hill, Craigleith, and Mansfield. (*13.*)

6. To what depth would you consider it necessary to carry the foundation of a church building on a solid clay soil in order to avoid future cracks and settlements? What limit of weight per square foot would you place upon such a formation? How would you spread the weight so as to secure a uniform pressure? (*12.*)

7. Describe the composition of greystone and blue lias limes and also of Portland cement. What qualities would you require in them, and what tests would you apply in proof? What characteristics are needful in sand and aggregate to produce the best mortar and concrete? (*14.*)

8. Show sketches of six mouldings in common use by the Romans and a like number of those practised by the 13th-century builders. (*12.*)

9. State the weight per foot cube and the crushing weight per square foot of the following stones, and say what proportion of the latter you would consider a safe load:—Portland Whitbed, Aberdeen granite, Corsham Down Bath, Doulting, Darley Dale, Anston, Forest of Dean, Pentelikon marble. (*20.*)

10. Describe the apparatus you would employ to hoist and set masonry, consisting of entablature with cornice, over a colonnade 20 ft. high from ground, the columns being 10 ft. apart, the maximum weight of any one stone being two tons. State the precautions you would adopt to protect your work from injury during the operation. (*10.*)

11. Show by sketches types of the following joints; define their true positions in masonry, and when they should be used:—Joggle joints (both visible and invisible), he and she joggles, dovetail joggles, overlapping joints, weather joints. (In answering this, show a sketch of the jointing you would adopt for the entablature described in question No. 10.) Describe the positions and functions of cramps when introduced. (*10.*)

12. State how you would arrange for the natural bed of a stone to stand in preparing cornices and quoins thereto, arch stones, thresholds, copings and window mullions, giving your reasons. What precautions would you adopt in setting pier stones, thresholds and window sills to avoid subsequent fracture? How would you arrange to joint a window sill 9 ft. long? (*10.*)

Grade I.

Written Examination, 1913.

1. Describe the methods, operations and apparatus necessary for the hoisting and fixing of stonework for a building stone-faced with the usual cornices and other overhanging stones. (*50 marks.*)

2. Describe the operations necessary to produce a 6-in. landing, 4 ft. 6 ins. by 4 ft. 6 ins., from the outer face of a York stone block 5 ft. 6 ins. by 6 ft. by 2 ft., assuming that hand power only is available. It has to be perfectly true and tooled on both faces and two edges, one of the latter being also splayed to receive the bird's-mouth edge of ascending step, the third edge to be roughly coped for building into wall, while the fourth is to have a he-joggle to take a similar landing adjoining. State the tools you would use in the whole operation, and give explanatory sketches if you think desirable. (*50.*)

3. What is the "natural" bed of a stone? Why should stones be set in a building upon this bed? Would you make any exceptions, and, if so, why? Would it make any difference if the stone were set horizontal on the bed, but upside down? (*40.*)

4. State the principal agents of destruction to external stonework. Name any precautions which you would consider it desirable to apply to a new structure to prevent disintegration. Name four stones which on this account you would decline to use in an external situation in a city (London, for example), and state four others you would prefer in place of them. (*40.*)

5. Sketch sections of the following types of mouldings:—Bird's-beak, Double Ogee, Scroll, Pointed Bowtell, Listel, Cavetto, Wave. (*40.*)

6. Set out to ¼-in. scale on your paper an ashlar stone facing, 8 ft. 6 ins. high, in six courses, with fair quoins each end, the wall being 15 ft. long. Show the jointing and mark the depths of the beds thereon so as to produce an average of 6¾ ins. depth. Number the stones so that the fixer may make no mistake in placing them. (*50.*)

7. Draw to ½-in. scale sections of the foundations of two stone-faced walls, one 1 ft. 4 ins. thick, and the other 1 ft. 9 ins. thick at base. State what purpose spreading footings serve, and if you consider that they are always necessary. Why is a damp course put in? What materials do you consider best for its composition? (*40.*)

8. Name four types of stone you have met with, which are similar to one another in colour and texture. State shortly the characteristics of each and for what class of work, and in what atmospheric conditions you consider each most suitable. (*60.*)

9. What is a waller? Sketch and name four diverse types of rubble facing, indicating in each case what measures you would adopt for sound construction and bonding. What thickness would you build a wall in the manner described to carry the same weight as one 16 ins. thick, ashlar-faced and brick-backed? (*45.*)

10. Show by sketches the following joints, and in what positions they would be properly introduced:—Joggle, bed joggle, bed dowel, saddle joint, table joint, keyed joint. (*30.*)

11. State the functions fulfilled by mortar in a stone wall. Of what materials would you make it, and what qualities would you look for therein? State the chemical changes that occur in the mixing of the ingredients and in the maturing of the mixture. State also whether in your opinion lime or cement makes the better mortar for masonry, and why you think so. (*35.*)

INDEX

THE END

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